GEOLOGICAL SURVEY BRANCH
DEPARTMENT OF MINES AND ENERGY
GOVERNMENT OF NEWFOUNDLAND AND LABRADOR

BARITE RESOURCES OF NEWFOUNDLAND

Ambrose P. Howe

Mineral Resource Report 6

St. John's Newfoundland

1992

COVER

The Cross Point barite vein near St. Bride's, Newfoundland

GEOLOGICAL SURVEY BRANCH
DEPARTMENT OF MINES AND ENERGY
GOVERNMENT OF NEWFOUNDLAND AND LABRADOR

BARITE RESOURCES OF NEWFOUNDLAND

Ambrose F. Howse

Mineral Resource Report 6

St. John's, Newfoundland
1992

EDITING, LAYOUT AND DRAFTING

Senior Geologist R.F. BLACKWOOD

Editor C.P.G. PEREIRA

Typesetting B. STRICKLAND

Word Processing J. BANTON
D. DOWNEY
J. MATTHEWS

Supervisor, Cartographic Services K. BYRNE

Cartography D. LEONARD (photomechanical)
T. PALTANAVAGE
T. SEARS

Publications of the Geological Survey Branch are available through the Publications and Information Section, Geological Survey Branch, Department of Mines and Energy, P.O. Box 8700, St. John's, Newfoundland, AIB 4J6.
Telephone: (709) 729-3159
Telex: 016-4724
Fax: (709) 729-3493

This project is a contribution to the Canada–Newfoundland Mineral Development Agreement 1984-1989; project carried out by the Newfoundland Department of Mines and Energy.

Author's Address: *Ambrose F. Howse*
Mineral Deposits Section
Geological Survey Branch
Department of Mines and Energy
P.O Box 8700
St. John's, Newfoundland
Canada
AIB 4J6

CONTENTS

Page

ABSTRACT ix

INTRODUCTION 1
PURPOSE AND SCOPE 1
FIELD INVESTIGATIONS 1
Previous Work 1
Present Work 1
MINERALOGY OF BARITE 2
Physical and Chemical Properties 2
TYPES OF DEPOSITS 2
Veins 2
Bedded Deposits 2
Residual Deposits 3
BARITE MINING AND PROCESSING METHODS 3
USES AND SPECIFICATIONS 3
Petroleum Exploration Application 3
Barite in Chemicals 4
Barium Sulphide 4
Barium Carbonate 4
Blanc Fixe 4
Barite as a Filler and Extender 4
Pharmaceutical Applications 5
Other Uses 5
PRODUCTION AND FUTURE OUTLOOK 6
Production 6
Prices 6
Competitive Materials and Trends 6

GEOLOGICAL SETTING OF BARITE IN NEWFOUNDLAND 7
INTRODUCTION 7
Avalon Zone 7
Gander Zone 7
Dunnage Zone: Central Mobile Belt 7
Humber Zone 9

AVALON PENINSULA BARITE OCCURRENCES 9
INTRODUCTION 9
Avalon Isthmus 9
Geology 9
Barite Veins and their Origins 10
Collier Point Barite Vein 12
Location and History 12
Description 13
Reserves 13
Tickle Cove Barite Veins 14
Tickle Cove Brook Barite Veins 15
Railroad Rockcut Barite Veins 15
South Rockcut 15
North Rockcut 16
Trans-Canada Highway Barite Showings 16
Sutton Vein 16
Doe Hill Vein 17
Powerline Veins 17
Little Southern Harbour Lead–Barite Vein 17
La Manche Lead Mine 18

Page

St. Bride's–Cape St. Mary's Barite Deposits ... 18
Geology ... 19
Barite Veins ... 20
Cross Point Vein ... 20
Cuslett Vein ... 20
Other Barite Occurrences ... 21

BURIN PENINSULA AND FORTUNE BAY BARITE OCCURRENCES ... 22
ST. LAWRENCE FLUORSPAR DISTRICT BARITE OCCURRENCES ... 22
Geology ... 22
Mineralization ... 23
Mineralogy ... 24
Barite in Outlying Veins ... 25
Meadow Woods Vein ... 25
Meadow Woods–East Extension Vein ... 25
Anchor Drogue Vein ... 27
Lunch Pond Vein ... 27
Clam Pond Vein ... 27
Main Brook Pond Barite Float ... 27
Lawn Barite Vein ... 27
Other Barite Occurrences ... 28
Oderin Island Barite Vein ... 28
FORTUNE BAY BARITE OCCURRENCES ... 28
Northeast Fortune Bay ... 29
Western Fortune Bay ... 29

PORT AU PORT PENINSULA AND BAY ST. GEORGE SUBBASIN BARITE–CELESTITE OCCURRENCES ... 29
INTRODUCTION ... 29
Ronan Deposit ... 31
Location and Assessment History ... 31
Geology ... 31
Reserves ... 31
Metallurgical Tests ... 32
Gilliams Cove Prospect ... 32
Other Occurrences ... 33
SUMMARY AND DISCUSSION ... 34

BAY ST. GEORGE SUBBASIN AND GREAT NORTHERN PENINSULA BARITE OCCURRENCES ... 34
INTRODUCTION ... 34
Geology ... 34
Barite and Associated Minerals ... 36
Barite in the Ryans Brook–Brooms Brook Area ... 37
Ryans Brook (South) Showing ... 37
Quarry Showing ... 37
Ryans Brook (North) Showing ... 37
Brooms Brook Vein ... 37
Bald Mountain Barite Occurrences ... 37
Trans-Canada Highway Occurrences ... 39
Snakes Bight ... 39
Barite Occurrences near Hawkes Bay, Great Northern Peninsula ... 39
CONCLUSION ... 39

CENTRAL NEWFOUNDLAND BARITE OCCURRENCES ... 39
BUCHANS TAILINGS DEPOSIT ... 39
Introduction ... 39
Barite Recovery Plant ... 40

Page

Reserves–Production 40
GLITTER POND PROSPECT 41

BAY D'ESPOIR AREA BARITE OCCURRENCES 42
GEOLOGICAL SETTING 42
Hardy Cove Vein 42

CONCLUSIONS 43

ACKNOWLEDGMENTS 43

REFERENCES 43

FIGURES

		Page
Figure 1:	The tectonostratigraphic zones of Newfoundland; also shown are the locations of significant barite occurrences	8
Figure 2:	Barite occurrences on the western Avalon Peninsula	10
Figure 3:	Geology of the Avalon Isthmus showing the locations of barite veins	11
Figure 4:	Graph showing the solubility of barite in water; 0.2 M NaCl along the vapour pressure (VP) curve and at a pressure of 500 bars (from Blount, 1977)	12
Figure 5:	Geology of the Cape St. Mary's Peninsula showing location of barite veins. Geology after Fletcher (1972)	19
Figure 6:	Geology of the St. Lawrence area (after Strong *et al.*, 1976)	23
Figure 7:	Location of the Meadow Woods and Meadow Extension veins; also shown are VLF airborne conductors and drillhole locations	26
Figure 8:	General geology and location of the Lawn barite vein (after Collins, 1984)	29
Figure 9:	Plan view of the Ronan barite–celestite deposit, Port au Port Peninsula (modified after Johnson, 1954)	30
Figure 10:	Block diagram of the Ronan barite–celestite deposit (modified after McArthur, 1973)	31
Figure 11:	Barite–celestite occurrences on the Port au Port Peninsula	33
Figure 12:	Sketch map showing location of barite occurrences in the Codroy–Anguille Mountains area (geology after Knight, 1983)	35
Figure 13:	Barite occurrences near Hawkes Bay, Great Northern Peninsula (after Knight and Boyce, 1984)	36
Figure 14:	Flow diagram of the barite recovery plant in Buchans	38
Figure 15:	Location of the Glitter Pond barite vein	41
Figure 16:	Location of barite occurrences in the Bay d'Espoir area (geology after Colman-Sadd, 1976)	42

PLATES

		Page
Plate 1:	Collier Point barite vein looking south along its strike	13
Plate 2:	New vein, Collier Point	13
Plate 3:	Vein B, Tickle Cove, Bellevue Peninsula	15
Plate 4:	Vein C, Tickle Cove, Bellevue Peninsula	15
Plate 5:	Barite vein exposed in south rockcut on the abandoned CN Railway line, near Jack's Pond	16
Plate 6:	One of several barite veins exposed in the north rockcut on the abandoned CN Railway line, near Jack's Pond	16
Plate 7:	Sutton barite vein adjacent to the Trans-Canada Highway near the La Manche overpass	17
Plate 8:	Barite coating joint plane; Avalon Isthmus	17
Plate 9:	Little Southern Harbour barite vein; note coarse galena crystal aggregates in barite and calcite	18
Plate 10:	Barite infilling splay fractures of the main La Manche fault on the shoreline at La Manche, Placentia Bay; note the barricaded entrance to the old lead mine to the left	18
Plate 11:	Cross Point barite vein near St. Bride's, Placentia Bay	20
Plate 12:	Otterrub barite vein near Cuslett, Placentia Bay	20
Plate 13:	Cuslett barite vein showing growth bands consisting of coarse, platy crystals	21
Plate 14:	Panoramic view of coastal cliffs near St. Bride's, Placentia Bay; note barite vein in middle of photograph	21
Plate 15:	Barite associated with fluorite, Tarefare vein system, St. Lawrence	25
Plate 16:	Trenched area, east of Main Brook Pond. Trenches contain granite boulders and barite–fluorite float	29
Plate 17:	Buchans tailings pond showing 'mud cat'	40
Plate 18:	Barite–quartz vein at Hardy Cove, Bay d'Espoir	42

TABLES

Page

Table 1: Drilling-mud grade specifications for barite 4

Table 2: Primary uses for barite fillers 5

Table 3: Product specifications for USP barium sulphate 5

Table 4: World barite production (tonnes) 6

Table 5: Prices for commercial grades of barite (1992) 6

Table 6: Assay analyses of barite samples from the Collier Point vein 14

Table 7: Assay analyses of barite samples from veins on the Bellevue Peninsula, Trinity Bay 16

Table 8: Assay analyses of samples taken from the Little Southern Harbour barite vein 18

Table 9: Assay analyses of samples from barite veins located near St. Bride's, Placentia Bay 21

Table 10: Average analyses of 12 run-of-mine samples from the Meadow Woods vein exploration shaft, St. Lawrence 27

Table 11: Assay analyses of some St. Lawrence fluorspar veins that contain barite as gangue 28

Table 12: Core and sludge samples from the Ronan barite–celestite deposit, Port au Port Peninsula 32

Table 13: Assay analyses of barite–calcite veins in the Ryans brook–Brooms brook area, Anguille Mountains 37

Table 14: Assay and screen analysis of a sample of the Buchans tailings composite (1970) 41

Table 15: Assays from the Glitter Pond barite prospect 41

Table 16: Assays from the Roti Point area, Bay D'Espoir 43

100-05749/

ABSTRACT

Oil and gas exploration in the Newfoundland offshore area has heightened interest in this province's barite, a commodity used mainly to control the density of drilling fluids. Non-drilling applications include use as filler, and in the production of speciality glass and barium chemicals. The purpose of this report is to summarize all the available data on Newfoundland barite and to provide pertinent geological data on the deposits.

Barite deposits of varying significance are found in each of the major tectonostratigraphic divisions of insular Newfoundland. The greatest number of occurrences is located in the Avalon Zone, where numerous small, high-purity vein deposits occur along the western Avalon Peninsula, with particular concentrations in the Avalon Isthmus and the St. Bride's–Cape St. Mary's areas. Typically, these veins consist of narrow (up to 1-m wide) bladed or tabular crystal aggregates occupying faults and commonly associated with quartz and/or calcite. They generally grade more than 90 percent barium sulphate ($BaSO_4$). One such vein, the Collier Point deposit in southeastern Trinity Bay, has intermittently produced barite for use in offshore drilling. Minor amounts of barite are present as gangue in some of the fluorite veins that occur in the Carboniferous St. Lawrence Granite at St. Lawrence on the Burin Peninsula. However, the amount of barite present in the well-known fluorite producers, near St. Lawrence, is significantly less than that present in veins located in the peripheral region of the district. Barite is also an accessory mineral in a tungsten-bearing quartz vein at Grey River.

In the Gander Zone, barite occurs in small veins as a gangue or accessory mineral at a number of locations around Bay d'Espoir.

The province's largest reserve of barite is located at Buchans, in the Central Mobile Belt of the Dunnage Zone, where approximately 1 million tonnes of recoverable mill tailings average about 35 percent $BaSO_4$. Also located near the deposit is a plant capable of recovering the barite.

On the western platform, deposits of mixed barite–celestite are found on the Port au Port Peninsula, where they replace Carboniferous age sedimentary rocks in restricted fault-bounded basins. The area has good potential for yielding additional deposits of economic interest. In the Bay St. George subbasin, barite is found in narrow calcite veins, which cut the Anguille Group sandstone beds and the overlying Ship Cove limestone.

INTRODUCTION

PURPOSE AND SCOPE

Current exploration for offshore oil and gas, and the anticipated development and production of these resources have increased the importance of industrial minerals and chemicals in Newfoundland and Labrador. Materials used in drilling fluids include barite, bentonite, salt, potash, soda ash, gypsum, anhydride, graphite, and quartz. By far the most important commodity used, both in terms of consumed tonnage and total value, is barite. About 90 percent of the world's production of barite is used as a weighting additive in drilling fluids. Depending on drilling conditions, barite accounts for 30 to 70 percent of the cost of the fluid.

The non-drilling applications of barite, which account for only 10 percent of the total annual production, are nevertheless wide and varied. They include fillers and extenders, chemicals, glass, and ceramics.

In response to the renewed interest in barite, the Geological Survey Branch of the Department of Mines and Energy initiated a project in 1982, aimed at assessing Newfoundland's barite deposits. The objectives of this study were to provide interested parties with pertinent data, and to stimulate others who are interested in investigating and developing barite, to consider this province as a potential primary source.

FIELD INVESTIGATIONS

Previous Work

The pioneer geologist, John Milne, first noted the presence of vein barite on the Avalon Peninsula exposed in the seacliff near St. Bride's (Milne, 1874). Now variously referred to as the St. Bride's vein and Cross Point vein, it was again mentioned by J.P. Howley in 1900 (Murray and Howley, 1918). During the period 1902-1904, the barite vein located at Collier Point in Trinity Bay was developed by the Collier Cove Barite Company and about 5 000 tonnes of barite were produced.

Chute (1939) noted the presence of barite in galena- and sphalerite-bearing calcite veins at La Manche and Silver Cliff in Placentia Bay. Jewell (1939) also observed barite in veins located in the Roti Point area of Bay d'Espoir but concluded that none were of economic interest, 'because of their small size and the presence of other minerals such as pyrite, sphalerite, galena, and fragments of slate'.

In 1951, the Collier Point barite vein again attracted some attention, when it was assessed by Toronto-based mining interests. They concluded that the deposit was too small to compete in the drilling-mud market, but that it might have potential as a producer of pure white barite if it could be bleached. Bleaching tests were carried out by the same group with successful results (Carr, 1958), but nothing further was done. McCartney (1967), who examined and sampled the vein during his regional mapping activities, suggested that the barite might be suitable for use as heavy aggregate for concrete in the coating of underwater pipes and for radiation shielding.

On the province's west coast, initial interest in the mixed barite–celestite prospects on the Port au Port Peninsula was spurred by the increased wartime (World War II) demand for strontium, a strategic commodity used in munitions manufacturing. Attention was thus focussed primarily on the celestite component of these deposits. In 1942-43, the deposit on Hoopers Brook near the community of Boswarlos was trenched and drilled, and a reserve of 135 000 tonnes of mixed barite–celestite identified (Johnson, 1954). The property was not developed; one of the reasons for not developing the property may have been the difficulty in separating the two minerals.

Interest in Newfoundland as a potential primary source of barite increased significantly after the late 1960's because of offshore oil and gas exploration. McArthur (1972) carried out a brief examination of barite occurrences along the coast of Trinity and Placentia bays. He also examined barite–celestite prospects on the Port au Port Peninsula and conducted a small drilling program on the Ronan (Hoopers Brook) deposit. The objective of the program was to obtain core samples for metallurgical tests.

The potential value of the barite contained in the Buchans mine tailings has been long recognized. Early interest was mainly concerned with possible use as filler and applications in paint and glass manufacturing. With the coming of offshore oil and gas exploration, attention focussed on its potential use in drilling fluids. This led to a more detailed investigation of the tailings (estimated to contain approximately 500 000 tonnes of barite) and the design of a recovery plant capable of producing a barite concentrate, which meets the specifications for use in drilling muds. To date, this plant has not realized its potential because of a combination of factors related mainly to the high cost of transportation, competition and markets.

Present Work

This project aimed to fulfil two objectives: (1) to summarize all the available geological information on significant barite occurrences in Newfoundland, and (2) to locate new deposits and identify areas with high potential for barite deposits. Work began with an island-wide survey of barite occurrences. On the Avalon Peninsula, several new veins were discovered (Howse and French, 1983). In western Newfoundland, the assessment took the form of a follow-up of barium anomalies, which had earlier been identified by regional geochemical stream-sediment surveys on the Port au Port Peninsula and in the Bay St. George subbasin (McArthur *et al.*, 1975). Several occurrences of base metals and minor barite–calcite veins were identified.

To achieve the second objective, geochemical surveys of stream sediments were conducted in selected areas. The first survey, a cooperative effort with the Geochemistry/ Geophysics and Terrain Sciences Section of the Geological Survey Branch, covered the Avalon Isthmus. The second survey covered the St. Bride's–Cape St. Mary's area, and a third project in 1984 covered the St. Lawrence fluorspar district. It is beyond the scope of this report to discuss the geochemical results of these surveys but the data on new showings are incorporated in this report. The results of the geochemical surveys are on open file (Howse *et al.*, 1984a, b, 1986) and readers are referred to these reports for additional information.

MINERALOGY OF BARITE

Physical and Chemical Properties

Naturally occurring barium sulphate is commonly known as 'barite', 'heavy spar' or 'barytes'. The last term is used in the United Kingdom and to a limited extent, elsewhere. The first, which is more common, is used in this report. The chemical formula for barite is $BaSO_4$, and in its pure form it contains 65.7 percent BaO and 34.3 percent SO_3. It is practically insoluble in water and has a hardness of 3.0-3.5 on Moh's scale. Its specific gravity, 4.5, is unusually heavy for a nonmetallic mineral. The mineral has a vitreous to pearly lustre, is transparent to translucent and its colour varies from white through shades of blue, yellow, red and pink, depending on the type and amount of impurities present. Barite crystallizes in the orthorhombic system, examples of which can be best seen in vein deposits where coarse-bladed crystal aggregates commonly occur. It can also occur in compact, fine grained, earthy forms that are most frequently seen in bedded deposits. It is a brittle mineral, which fractures unevenly, but possesses a perfect cleavage.

Barium, with an atomic radius of 1.35 Å can substitute for elements such as potassium (1.33 Å) and strontium (1.12 Å). Thus, it occurs in many minerals even though its average content in crustal rocks is only 425 g/t. Barium commonly is deposited as the sulphate barite, or the carbonate witherite.

TYPES OF DEPOSITS

Barite is found in a variety of geological environments. It is found in three geologically different kinds of deposits, (i.e., veins, bedded deposits and as residual deposits) and occurs either alone or in combination with such minerals as fluorite, celestite, quartz, calcite, dolomite, sphalerite and chalcopyrite.

Veins

Vein deposits are those formed in openings in the earth's crust such as faults, joints, bedding planes, solution channels and breccia zones and barite is precipitated from fluids possibly of hydrothermal origin. Such veins are typically narrow but may pinch and swell. They are generally steeply dipping, but there are extreme variations in length, depth and attitude. The veins are usually of high purity but commonly contain varying proportions of quartz, calcite, fluorite, and sulphide minerals. Contacts of the veins with their host rocks are commonly sharp. Textures of vein-barite range from coarse-bladed crystals to fine-grained material. The colour varies from white to grey, and various shades of red and pink.

Mining of vein deposits is costly because it usually involves expensive underground techniques. In most cases, vein barite is extracted as a by- or co-product of lead–zinc mining, as in Sardinia, Italy, or as a co-product from fluorspar mining as in some operations in the Kentucky–Illinois fluorspar district. In Canada, barite for filler applications, has been produced since the early 1970's from a vein deposit near Matachewan, Ontario. In southeastern British Columbia, underground mines at Brisco and Parson have been in continuous production since 1945, with most of current production used in drilling muds for the Alberta oil and gas fields. In Newfoundland, the Collier Point vein was worked sporadically in the 1980's.

Bedded Deposits

Bedded deposits are commercially the most important type. They are commonly stratiform, usually the result of limestone replacement such as in the former major producer at Walton, Nova Scotia, and the marginally economic mixed barite–celestite deposits on the Port au Port Peninsula. Extensive bedded replacement deposits occur in Nevada and Arkansas, in the United States. Barite can also occur with stratiform massive sulphide deposits such as the Kuroko deposits of Japan and the Kuroko-like polymetallic massive sulphide bodies at Buchans, Newfoundland. The barite deposits associated with gold mineralization at Hemlo, north of Lake Superior, are of bedded type.

The colour of bedded barite is usually dark grey to black because of organic impurities. It is typically fine grained and may occur in beds up to 15 m thick. The barite content can be as high as 95 percent but the presence of fine-grained quartz, clay, pyrite, chert, or silt may reduce the grade to 50 percent or less.

Harben and Bates (1984) reviewed the different theories that have been developed to explain the origin of bedded barite deposits, a controversial subject because of apparently conflicting hydrothermal and sedimentary field evidence in certain deposits. In Arkansas, a model was envisaged whereby brines seeped out of shelf deposits, collected in sea-floor depressions, and mixed with seawater, causing barite to precipitate. Alternatively, barium ions could have been adsorbed onto clay particles and combined with sulphate (Hanor and Baria, 1977). Another theory is based on the fact that barium ions fit well into the lattice of aragonite, thought to be the primary form of calcium carbonate. Thus, barium may have been trapped in aragonite during early precipitation of marine carbonates, and expelled when aragonite was converted to either calcite or dolomite, minerals in which the barium ion does not fit. The barium could have then combined with sulphate to form barite deposits (Brobst, 1980).

In order to explain why certain bedded barite deposits contain evidence of both hydrothermal and sedimentary activity a submarine-exhalative genesis has been postulated. In this model, barium ions derived from submarine hot springs combine with sulphate in seawater to form a barite precipitate. Sedimentary features were thus formed and subsequent activity resulted in replacement and alteration (Harben and Bates, 1984).

Residual Deposits

Residual deposits consist of surficial accumulations of barite fragments and nodules in a layer of soil or clay, resulting from the erosion of pre-existing barite bearing rocks. In some cases, the source is a group of narrow barite veins in limestone or dolomite. Barite fragments range in size from sand to boulders, and deposits vary considerably in size and shape. Thicknesses range from less than 3 m to more than 45 m, and the shape of the deposit may reflect the structure of the original vein. Commerical-grade residual deposits of barite are found in the United States, in Georgia and Missouri. Mining such deposits is profitable, despite relatively low barite content (sometimes as low as 10 percent $BaSO_4$) because only screening and washing of the residual material is required to recover the barite. The potential for finding commercial residual deposits of barite in glaciated areas, such as Newfoundland, is low.

BARITE MINING AND PROCESSING METHODS

Barite mining employs conventional methods and techniques both in surface and underground operations. Bedded and residual deposits are commonly worked by open pits and quarries. Vein deposits are usually mined by underground methods although their initial development may involve surface open cuts.

Residual deposits, such as those in Missouri, Georgia and Tennessee can be worked simply be scraping away topsoil and excavating the ore (lumps of barite in unconsolidated clay) with power shovels, draglines and front-end loaders. In this type of operation, separation of barite from residue is accomplished simply by washing and screening. The final barite concentrate is produced by jig milling.

Bedded deposits, such as those located in the Battle Mountain and Toguima Range areas of central Nevada, occur in sedimentary beds up to 15 m thick. Open-pit mining methods are used to mine the ore. The barite is so pure in some deposits that it simply needs to be washed and crushed before shipment.

In underground operations both shrinkage-stoping and block-caving methods have been used. These techniques were employed at Walton, Nova Scotia, where a massive deposit grading better than 90 percent $BaSO_4$ was mined from 1941 to 1978. The sugary textured, pink and white barite apparently replaced limestone of Mississippian and Triassic age. The deposit was initially quarried to depths of about 100 m, and subsequently mined by a block-caving method. Originally, the barite ore was shipped untreated but in later years the barite was upgraded by heavy-media separation and jigging.

Vein deposits in Ontario have been mined on a small scale by open-cut and shrinkage-stoping techniques. Hand cobbling, to remove rock fragments, jigging and tabling have been used to improve the ore quality.

Barite is a common gangue mineral in copper, zinc, lead and silver veins throughout the world and in some cases it is recovered as a by-product when these deposits are mined. However, in other cases the barite is not recovered in the initial mining and milling operations for these metals but is allowed to escape along with other impurities and waste products into tailings ponds or reservoirs, from which it can be later recovered.

Barite has been recovered from lead–zinc tailings at Buchans, Newfoundland, and at the Mineral King Mine near Ivermere, British Columbia.

In a somewhat unique method of mining, barite is drilled and blasted underwater, off Castle Island near Petersburg, southeastern Alaska. It is recovered by a crane equipped with a special digging bucket and is loaded into barges.

USES AND SPECIFICATIONS

Petroleum Exploration Applications

In the oil and gas exploration industry, barite is used in drilling fluids or muds. Drilling muds have five main functions: (1) transport drill cuttings to the surface; (2) control formation pressures; (3) maintain borehole stability; (4) protect producing zones; and (5) cool and lubricate the bit and drill string. The mud must also provide a wall cake to prevent egress of the drilling fluid into permeable low-pressure rock formations and they must be electrically conductive so as to allow passage of current when electrical surveys are conducted in the hole. Its principal function, as a weighting agent, is to suppress high formation pressures and prevent blowouts. As the well is drilled, the bit passes through various formations, each with different characteristics. The deeper the hole, the more barite is needed as a percentage of the total mud mix. The mineral provides a unique combination of properties–high specific gravity, low reactivity and low abrasivity among them–which cannot be matched by any other naturally occurring or synthetic material (Guillet and Kriens, 1984).

The ground barite used in drilling must meet a specific gravity specification of 4.2 or higher. Pure barite has a specific gravity of 4.5, hence between 10 and 15 percent of contaminants can be tolerated, depending upon their individual densities. However, it is the types and quantities of contaminant, which ultimately decide whether the material will be suitable. For example, too much clay may cause

excessive viscosities and too much calcite could effect the flow properties of the fluid. The soluble salt content should also be less than 1 percent. Table 1 summarizes current consumer specifications for drilling-mud barite and also shows particle-size requirement.

Table 1. Drilling-mud grade specifications for barite

Specific gravity	4.2 min
$BaSO_4$ content	92 % min
Soluble alkaline earth content, as calcium	250 ppm max
Particle size	325 mesh

Source: Collins and Andrews (1988)

Barite in Chemicals

It has been estimated that of the total 1982 world barite production of 7.4 million tonnes, about 0.6 to 0.65 million tonnes (*ca.* 8.7 to 9 percent) was used for the production of barium chemicals. Griffiths (1984), in a comprehensive account of the non-drilling applications of barite, reviewed the various chemicals that are currently produced.

Barium Sulphide

Barium sulphide (black ash), derived from barite, forms the starting point for most barium chemicals. It is produced by the reduction of barite ($BaSO_4$) with finely powdered coal in a rotary kiln at a temperature between 1 100 and 1 250°C. The end product contains about 80 to 85 percent BaS depending on the impurity content of the starting materials. The product is further upgraded by counter-current leaching of the furnace clinker with water and filtration to produce a barium sulphide solution and a leach residue containing most of the impurities.

Barium Carbonate

Quantitatively, barium carbonate is the most important of all the barium chemicals. It is a raw material for the production of many other compounds but it is also used in brick and tile manufacturing to control scum as a result of gypsum or magnesium sulphate in the clay and to diminish the porosity and prevent discolouration in bricks. Other uses are in television picture tubes, optical glass, ceramic glazes, porcelain enamel-ferrites and miscellaneous ceramic products. It should be noted that its application in colour television picture tubes has been largely replaced by strontium chemicals. Barium carbonate is produced chemically using barium sulphide (black ash) as the starting material.

Blanc Fixe

Blanc Fixe, chemically precipitated barium sulphate, is used as a white filler in paints, rubber, ink and other material where a higher degree of purity is required than is found in natural barite.

Barium chloride can be produced directly from barium sulphide by reacting with hydrochloric acid or chlorine gas or through the reaction of barium carbonate and hydrochloric acid. It is used in case-hardening and heat-treating baths, in leather and cloth, in making magnesium metal, water treatment, and as a laboratory reagent.

Barium nitrate is used in green signal flares, tracer bullets, primers and detonators, and enamels.

Barium oxide is used in electric furnaces, ferrous metallurgy, increasing the life of acid furnace linings, to give a quieter and steadier arc, and to reduce the sulphur content of the iron and lower slag viscosity. Barium peroxide is manufactured from barium oxide.

Barium hydroxide prevents scumming in ceramics and is used in lubricating oils and to recover sugar from molasses by the barium saccharate process.

In order to meet specifications for the chemical industry, the barite grade must be at least 95 percent $BaSO_4$ and impurities restricted to less than 1 percent iron oxide, 1 percent strontium sulphate, and only traces of fluorine. Size specifications range between 4.757 and 0.841 mm.

Barite as a Filler and Extender

One of the most important applications for barite, outside of drilling, is as a filler and extender. The paint industry is the largest consumer of filler-grade barite and its derived barium salts. This is because barite possesses, in addition to the properties already mentioned, low oil absorption, easy wettability by oils, and good sanding qualities. However, according to a study on the non-drilling application of barite (Griffiths, 1984), its usage in domestic paints has decreased considerably since the introduction of large volume paint sales, which has resulted in the replacement of filler-grade barite by cheaper and less dense fillers such as calcium carbonate and dolomite. Table 2 summarizes the applications and general specifications for filler barite.

Barite is used as a filler for primer coats in automobile paint because it (and Blanc Fixe) produces a high degree of impermeability and durability through their close packing density. They are particularly useful in undercoats preventing the absorption of top coats, filling scratches and resisting sanding marks. Unlike calcium carbonate, they do not contain water soluble materials and thus are not likely to blister when water is present.

Barite is used as a filler or extender in some plastic and rubber products. It is used in such products as floor mats and carpet backing to increase density and improve processing qualities. Small quantities are used in making white sidewall tyres.

Table 2. Primary uses for barite fillers

Application	Function	General Specifications
Trade-Sales Paints	To Provide a high density inert paint film.	High brightness; controlled particle size, low oil absorption, chemically bleached grades are commonly used.
Industrial and Automotive Primers	To provide dense inert paint films with good sampling properties.	Medium brightness; fine particle size; low oil absorption.
Plastics	As a filler in polyurethane foams, used in furniture and bedding; also in automotive carpeting as foam backing. Minor uses in polyethylene and chemical resistant vinyl floor tile.	Medium brightness; natural barite. High brightness or bleached grades used in polyethylene and vinyl tile. Medium- to fine-particle sizes.
Rubber	Used in white sidewalls of automotive tyres, and in sporting goods.	High brightness; fine barite, low abrasiveness.
Putty Chalk and Sealants	To provide density and chemical inertness.	High brightness; natural or bleached barite of fine particle size.
Carpet Backing	To increase foam density and sound deadening.	Medium brightness; medium fine barite.

Source: Guillet and Kriens (1984)

The paper industry uses small quantities of barite filler. White and dense barite coating serves as a base for the sensitized layers in photographic prints.

Barite is used in the glassmaking industry to flux the heat-insulating froth that forms on the melt surface, thus saving fuel. It also acts as an oxidizer and decolourizer making the glass more workable and increasing its brilliance. There are no standard specifications for barite used in the glass industry. Generally, the barite must contain about 97 percent $BaSO_4$, with a maximum Fe_2O_3 content of 0.1 to 0.2 percent. The size specifications vary from 1.189 to 0.149 mesh (maximum and minimum respectively).

Another minor use for barite (2 percent of total barite consumption) includes ballast for ships, heavy concrete aggregate for radiation shielding, and applications in foundries.

Pharmaceutical Applications

A strong market demand for pharmaceutical barite led to the development of a barite deposit near Brookfield, Nova Scotia (Stone *et al.*, 1980). A processing plant at Debert, Nova Scotia produces x-ray barium sulphate by subjecting the ore from Brookfield to magnetic separation for the removal of iron minerals, fine grinding by paddle milling to less than one micron, and acid leaching. The product, UPS barium sulphate, is the basic ingredient in the preparation of mixtures used in the x-ray diagnosis of diseases of the gastro-intestinal tract. In addition to barium sulphate, the mixtures include certain laxatives, flavour, dispersants and colouring. The annual capacity of the Brookfield operation (2 000 tonnes per year) of end products represents about 15 percent of the North American market. Product specification requirements for USP barium sulphate are listed in Table 3. Griffiths (1992) reports that the reserves at Brookfield are sufficient for only ten years at the current rate of production. Thus the operators, (Nystrone Chemicals Ltd.), are very interested in finding an alternate source of high-grade barite.

Table 3. Product specifications for USP barium sulphate

$BaSO_4$	97.5% minimum
Colour	white or near white
Odour	odourless
Heavy metals (as pb)	10 ppm maximum
Arsenic	1 ppm maximum
Acid-soluble substance	0.3% maximum
Soluble barium salts	to pass test
Phosphate	to pass test

Source: Stone *et al.* (1980)

Other Uses

A product, which combines finely ground barite and synthetic rubber has been developed (Haines, 1979). This material, which is marketed under the trade name rubarite, is added to asphalt and used in road, airstrip, and parking lot construction. It is reportedly one of the simplest and economical ways to incorporate rubber into hot asphalt. This adds a more flexible seal coat resulting in less cracking of the surface and longer road-surface life.

PRODUCTION AND FUTURE OUTLOOK

Production

World production of barite is closely tied to global petroleum drilling. A high level of such activity in the early 1980's, caused by rising oil prices, was reflected by marked increases in barite production. This production peaked in 1981 at 8.5 million tonnes. However, in recent years volatile crude oil prices have depressed exploration drilling with a corresponding negative impact on barite production. In 1990, world barite production amounted to 5.6 million tonnes.

Table 4 lists the major barite producing countries. China is the dominant producer, accounting for almost 30 percent of total world production in the period 1987–1989. Other major producers are Mexico, India, CIS (formerly the USSR), the United States and Turkey. Canadian production in 1989 was about 38 000 tonnes, which came from three provinces, Nova Scotia, Ontario, and British Columbia. There has been no barite produced in Newfoundland since 1983, when about 2 000 tonnes were produced at Collier Point. The previous year (1982) about 4 240 tonnes were recovered from the Buchans tailings deposit. Both operations are now inactive.

Prices

Publications such as *Industrial Minerals*, have regular listings of prices for industrial commodities including the different marketable grades of barite. Table 5 shows barite prices as of March 1992. One should remember that these quotations serve only as a guide to the prices obtained by producers and dealers because actual figures vary widely according to type, source, quality, quantity purchased and applications.

Competitive Materials and Trends

Barite has few competitors because of its unique density (for a non-metallic mineral), low abrasiveness, and chemical inertness. Various heavy metallic compounds such as magnetite, galena, and calcined pyrite (Fer-O-Bar) have been considered as substitutes for barite in drilling muds but have generally proved to be more abrasive, more expensive and harder to handle. Hematite is sometimes used as a weighting agent in drilling fluid, particularly in the drilling of high-pressure zones. Its specific gravity of 5.26 is higher than that of barite but it is also a harder mineral and therefore more abrasive to equipment. Hematite is also significantly more expensive than barite.

Calcium carbonate, because of price, is being substituted for barite in some paint and plastics, even though the final product is less desirable.

The demand for barite is determined by the scale of oil exploration. One trend that should be noted, however, is the increasing tendency by oil companies toward recovering used drilling muds for re-use. This may partly explain the decrease in the average amount of barite consumed per metre of drilling in the United States. However, despite this trend, deep-hole offshore well drilling, and the inevitable problems in some holes associated with lost mud circulation will result in the continuous use of large quantities of nonrecoverable mud; this will ensure that larger quantities of barite will still be required.

Table 4. World barite production (tonnes)

Country	1987	1988	1989
China	1,133,750	1,360,500	1,541,900
Mexico	364,011	485,203	513,362[e]
CIS (USSR)	489,780	489,780	489,780
India	224,029	356,451	358,265
United States	368,242	366,428	263,030
Turkey	267,094	351,673	417,220
Morocco	130,157	291,656	290,240
West Germany	157,233	167,000[e]	160,000
France	94,373	100,000[e]	100,000[e]
Brazil	92,826	85,287	95,000
Iran	81,630	81,630	81,630
Ireland	63,490	75,281	77,095
Italy	74,050	77,149	77,548
United Kingdom	73,793	68,932	72,560
Poland	66,301	68,025[e]	68,025
Romania	65,304	65,304	63,490
Algeria	54,420[e]	54,420[e]	54,420
Czechoslovakia	54,420	54,420	54,420
Belgium	36,280	31,745	36,280
Canada	**38,094**	**46,257**	**38,094**
Chile	47,262	39,123	36,280
Thailand	30,266	36,812	36,280
Argentina	30,350	44,326	36,280
Other	229,797	173,668	219,630
World Total	4,266,952	4,971,070	5,180,829

(e) estimate
Source: Ampian (1989)–U.S. Bureau of Mines

Table 5. Prices for commercial grades of barite (1992)

Ground, white, paint grade, 96 to 98 percent $BaSO_4$	
99 percent 350 mesh, 1-5 tons, del. UK	£150-£190
Micronised, min. 99 percent finer 20 microns, del. UK	£140-£150
Unground, OCMA grade bulk, FOB Morocco	$ 40
Ground OCMA* grade bulk, del. Aberdeen	£ 45-£ 52
FOB Gulf Coast, API**, ground, wholesale	$ 70-$ 75
BOB Gulf Coast, PI, ground, retail	$115

* OCMA = Oil Companies Materials Association (U.K.)
** API = American Petroleum Institute (U.S.A.)

Source: Industrial Minerals, March, 1992

GEOLOGICAL SETTING OF BARITE IN NEWFOUNDLAND

INTRODUCTION

Insular Newfoundland represents a cross-section of the Appalachian–Caledonian orogen, a mountain belt that extends from the southeastern United States along the Atlantic seaboard and through Canada's Atlantic provinces. Beyond Newfoundland, the belt has been fragmented by the opening of the Atlantic Ocean but is recognized in Ireland, Britain, Scandinavia, Greenland and western Europe. Williams (1964) first postulated a two-sided symmetry of Newfoundland geology consisting of eastern and western platforms flanking a central volcanic belt. His original concept has since evolved into a tectonostratigraphic division of Newfoundland geology into four zones (Williams, 1979; Figure 1). These tectonic zones (Humber, Dunnage, Gander and Avalon) are based on the contrasting development of pre-Middle Ordovician rocks. Rocks of the Humber Zone record the evolution and destruction of the continental margin of ancient eastern North America. The Dunnage Zone contains ophiolite suites and volcanic complexes that collectively represent remnants of an early Paleozoic ocean whereas the Gander Zone comprises the eastern margin of that terrane. Rocks of the Avalon zone represent elements of an easterly Upper Precambrian–Cambrian continental terrane.

Barite deposits of varying significance (i.e., indications, showings, and deposits) occur in all four zones.

Avalon Zone

Most of Newfoundland's barite occurrences are vein-type and most are found in the Avalon Zone. The Avalon Zone consists of variably folded Upper Precambrian (Hadrynian) volcanic and sedimentary rocks that are overlain by a Cambro-Ordovician shale–sandstone–limestone succession. Metamorphism ranges from prehnite–pumpellyite to greenshist facies. The entire sequence was intruded by plutonic rocks ranging in age from Late Hadrynian (Latest Precambrian) to Carboniferous. Barite occurrences are concentrated in two broad areas on the eastern and western shores of Placentia Bay. In the former, barite veins are found along the western side of the Avalon Peninsula including the Avalon Isthmus and St. Bride's areas. More than 50 barite veins have been documented in this area. On the Burin Peninsula, barite is found mainly as a gangue mineral in fluorspar veins in the St. Lawrence fluorspar district, usually in amounts grading less than 10 percent. However, there are deposits in the peripheral regions of the district where barite comprises more than 30 percent of the constituent minerals in the veins (Smith, 1957; Howse and Collins, 1984).

Minor amounts of barite associated with late-stage fluorite veins occur in the Grey River tungsten prospect situated near Ramea. The tungsten prospect occurs within an east-west trending belt of metasedimentary and granitic rocks. Fluorite and minor barite fill tension fissures that cut the main hydrothermal vein system (Higgins, 1980).

Very small amounts of barite have been documented in the Cambrian manganese beds in the Topsail and Manuels River areas on the east side of Conception Bay. At the head of Fortune Bay, and both sides of the bay, minor occurrence of barite (and fluorite) are found in veinlets of quartz and calcite.

Gander Zone

The Gander zone (Williams *et al.*, 1979) comprises a belt of polydeformed and metamorphosed sedimentary and volcanic rocks and gneisses that exhibit a complex tectonothermal history. The belt crosses Newfoundland in a generally north-south direction before curving sinuously westward along the south coast, where it defines the S-shaped configuration known as the Hermitage Flexure. This name was proposed by Williams *et al.* (1970), who hypothesized that its curving shape was due to large-scale Acadian folding about a north-south axial surface. However, Brown and Colman-Sadd (1976) presented detailed structural data, which suggested the flexure is an internal and original characteristic.

Barite in association with vein-type sulphides occur in several geographic areas within the Gander Zone. Many of the sulphide showings are small and in most cases the barite component is relatively minor.

Dunnage Zone: Central Mobile Belt

The largest reserves of barite in Newfoundland are contained in two tailings ponds or reservoirs at Buchans in central Newfoundland. The mill tailings, which average about 35 percent barite, accumulated as a result of the mining and milling of several baritic, polymetallic, massive sulphide deposits in the immediate Buchans area. The deposits are hosted by the Buchans Group, a complex assemblage of mafic to felsic volcanic rocks of early Middle Ordovician age (Nowlan and Thurlow, 1984; Dunning *et al.*, 1987). These ore bodies, which were mined continuously from 1928 to 1984, contained about 23 percent barite as a gangue mineral. Prior to 1965, the mill tailings were dumped into Red Indian Lake and are considered unrecoverable. However, there is an estimated 1.5 million tonnes of recoverable material in the two controlled tailings ponds.

Volcanic rocks of the Cambro-Ordovician Victoria Lake Group are host to a barite prospect located about 10 km southwest of Red Indian Lake. The showing, called the Glitter Pond prospect consists of mixed barite and quartz containing minor clots and bands of pyrite. Barite appears to be the dominant mineral in the deposit.

Barite occurs as a gangue (up to 30 percent) in polymetallic mineralization that was discovered on Oil Islands, a group of three small islands near Long Island in western Notre Dame Bay (McHale and McHale, 1981). According to Dean (1977), the islands are underlain by the

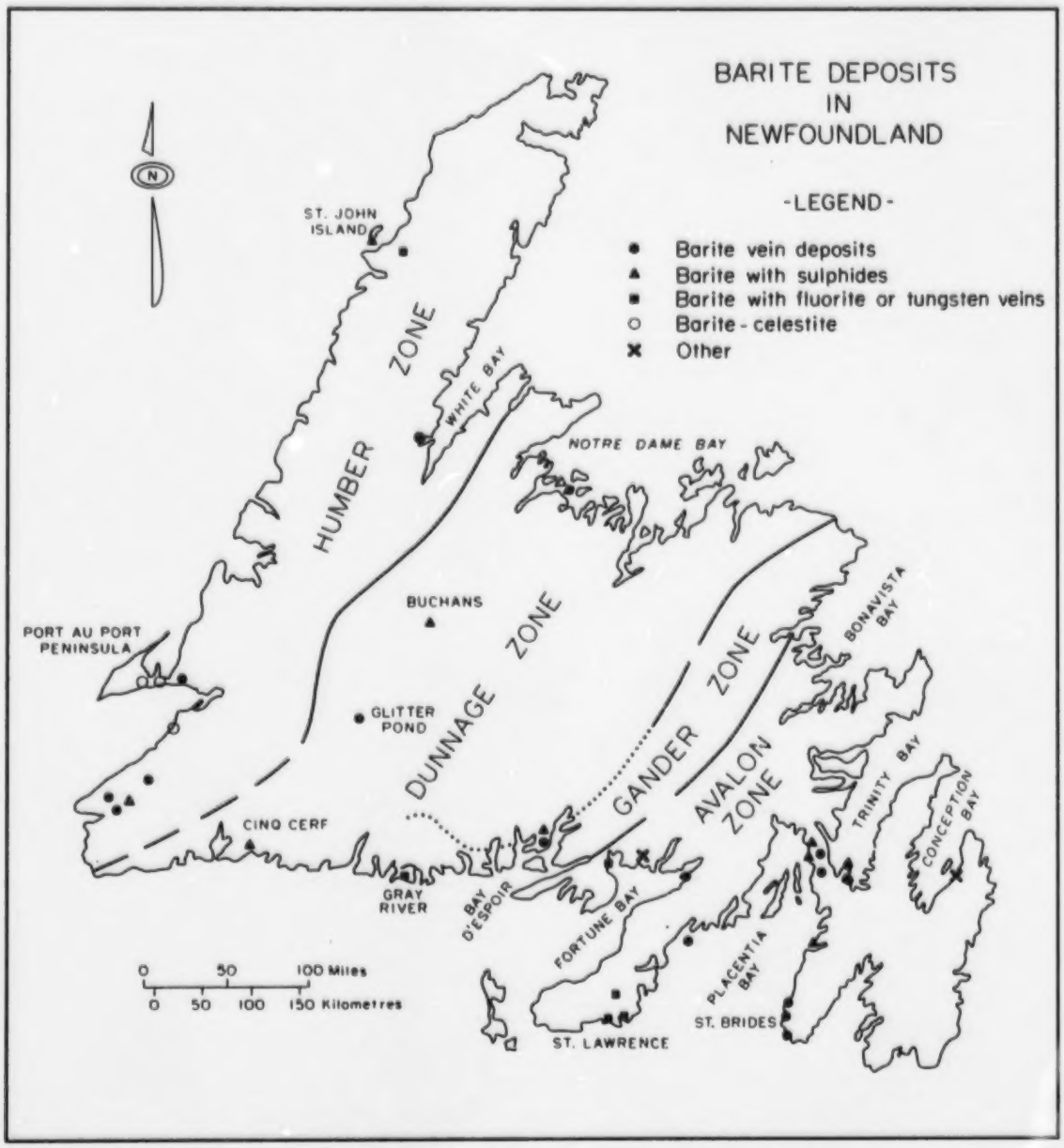


Figure 1. *The tectonostratigraphic zones of Newfoundland; also shown are the locations of significant barite occurrences.*

Lower and Middle Ordovician Cutwell Group volcanic and sedimentary rocks. As exposed on the islands, these rocks consist of a complex sequence of rhyolitic to andesitic pyroclastic and volcanic rocks. The uneconomic deposit, as shown in drill core, consists of lens shaped pods of galena, sphalerite, chalcopyrite, and barite.

In the Bull Road copper–lead zinc prospect on Pilley's Island, Dean (1977) described the occurrence as consisting of pyrite, chalcopyrite and galena disseminations and blebs in dacitic agglomerate. The deposit is hosted by rhyolite and dacite flows and agglomerate, which are part of the Ordovician Roberts Arm Group.

Both the Oil Islands and Bull Road Prospects are 'Buchans Type' deposits (see Dean, 1977). One of the diagnostic features of Buchans type, i.e., Kuroko-like deposit, is that barite locally occurs as a capping on massive ores, or as fragments in brecciated ore.

Barite in association with vein-type sulphides occur in several localities in Baie d'Espoir. Many of the sulphide

showings are small and in most cases, the barite component is relatively minor. The best concentration of such veins are found on or near the north shore of Lampidoes Passage. In one occurrence (Hardy Cove), barite is the main mineral constituent. The showings occur in metasediments of the Baie d'Espoir Group.

Humber Zone

Nearly all of the known occurrences of barite in the Humber Zone occur in Carboniferous rocks in the Bay St. George subbasin and on the Port au Port Peninsula. The basin, which is believed to have formed as a result of dextral strike-slip movements along the Long Range Fault, contains sedimentary rocks about 10 km in thickness, ranging in age from Late Devonian to Late Carboniferous (Knight, 1983).

The strata have been divided into three groups; the Anguille, Codroy and Barachois groups (Bell, 1948). The basal Anguille Group consists of non-marine sandstone and shale. The overlying Codroy Group consists of alternating marine and non-marine deposits; shale, sandstone, limestone and gypsum are the predominant rock types. Limestone and evaporites are confined, for the most part, to the lower sections of the Codroy Group. The Ship Cove limestone, an important marker, is the basal unit of the Codroy Group. The uppermost part of the Carboniferous section is the Barachois Group, which consists predominantly of non-marine siltstones and sandstones. Thin coal seams also occur in the group.

Occurrences of base metals and industrial minerals are widely distributed throughout the Bay St. George subbasin and on the Port au Port Peninsula. These range in size and importance from small indications and showings to delineated (although uneconomic) prospects such as the Ronan barite–celestite deposit to producing operations such as the Flat Bay gypsum quarry.

Lead–barite–pyrite mineralization hosted by Silurian limestone dolomite breccias occur in the Turners Ridge–Gales Brook area of southern White Bay. Discovered by Noranda Exploration Company Limited in 1976, the prospect has been assessed by geological mapping, ground geophysics (I.P.) and diamond drilling (Dimmell, 1978; Crowley, 1978). The uneconomic mineralization, which is stratabound within the limestone dolomite unit of Silurian age, has been traced for about 15 km along its strike. The lead, barite, pyrite and rare chalcopyrite is confined to the breccia matrix.

AVALON PENINSULA BARITE OCCURRENCES

INTRODUCTION

Documented barite occurrences on the Avalon Peninsula are mainly concentrated in two geographical areas, the Avalon Isthmus and the St. Bride's–Cape St. Mary's region (Figure 2). About midway between these areas, near Argentia, barite is found as a very minor gangue mineral at the Silver Cliff lead–zinc–silver deposit. All of the deposits are vein-type and they cut strata of all ages from the Late Precambrian Connecting Point Group to the various Early Cambrian formations.

Avalon Isthmus

The regional geology of this part of the Avalon Peninsula was mapped and described by McCartney (1956), who also mapped the Holyrood, Argentia, Dildo, and Sunnyside areas (1954, 1956 a, b, 1958). He later (McCartney, 1967) produced a memoir and geological compilation map of a 4300 km² block comprising a major portion of the Avalon Peninsula. More recent studies have been carried out by King (1979, 1988) and O'Driscoll and King (1985).

Geology

The oldest rocks in the area are Proterozoic turbidites and tuffs of the Connecting Point Group, which underlie the northwestern part of the isthmus. Distinguishing features of these rocks include laminated bedding, predominance of fine grained sediments and abundant basic dykes. The oldest exposed rocks in this area are laminated siltstone, slate, and siliceous argillite having minor greywacke, exposed near Jack's Pond Provincial Park. These rocks are overlain by a thick succession of black argillite and green-grey greywacke. The youngest rocks in the group consist of tuffs and siltstone commonly cut by epidote veinlets. These rocks form much of the coast from Little Southern Harbour to La Manche. The thickness of the Connecting Point Group has been estimated by McCartney (1967) to exceed 2700 m.

The Connecting Point Group is unconformably overlain by the Bull Arm Formation, the lowest formation of the Musgravetown Group. The Bull Arm Formation comprises basaltic and rhyolitic volcanic rocks, pyroclastic and volcanic sediments having a variable aggregate thickness of about 2400 m. A representative cross-section of the formation is exposed on the shore of Placentia Bay from Fair Haven north to Pinchgut Point. Mafic rocks form about one-half of the total formation, tuffaceous and sedimentary rocks about one-quarter, and felsic rocks the remainder. The Bull Arm Formation underlies most of central, eastern and northeastern portions of the Avalon Isthmus.

Bellevue Peninsula and Collier Point are underlain by sedimentary rocks of the Hodgewater Group, which consist mainly of green arkose, siltstone, and conglomerate. The conglomerate beds are thin except for a massive member, 10-m-thick, which occurs on the west side of the Bellevue Peninsula from Tickle Harbour Point southward to the village of Bellevue. The Snow's Pond Formation is characterized by the wavy irregular bedding of dark grey to black argillaceous,

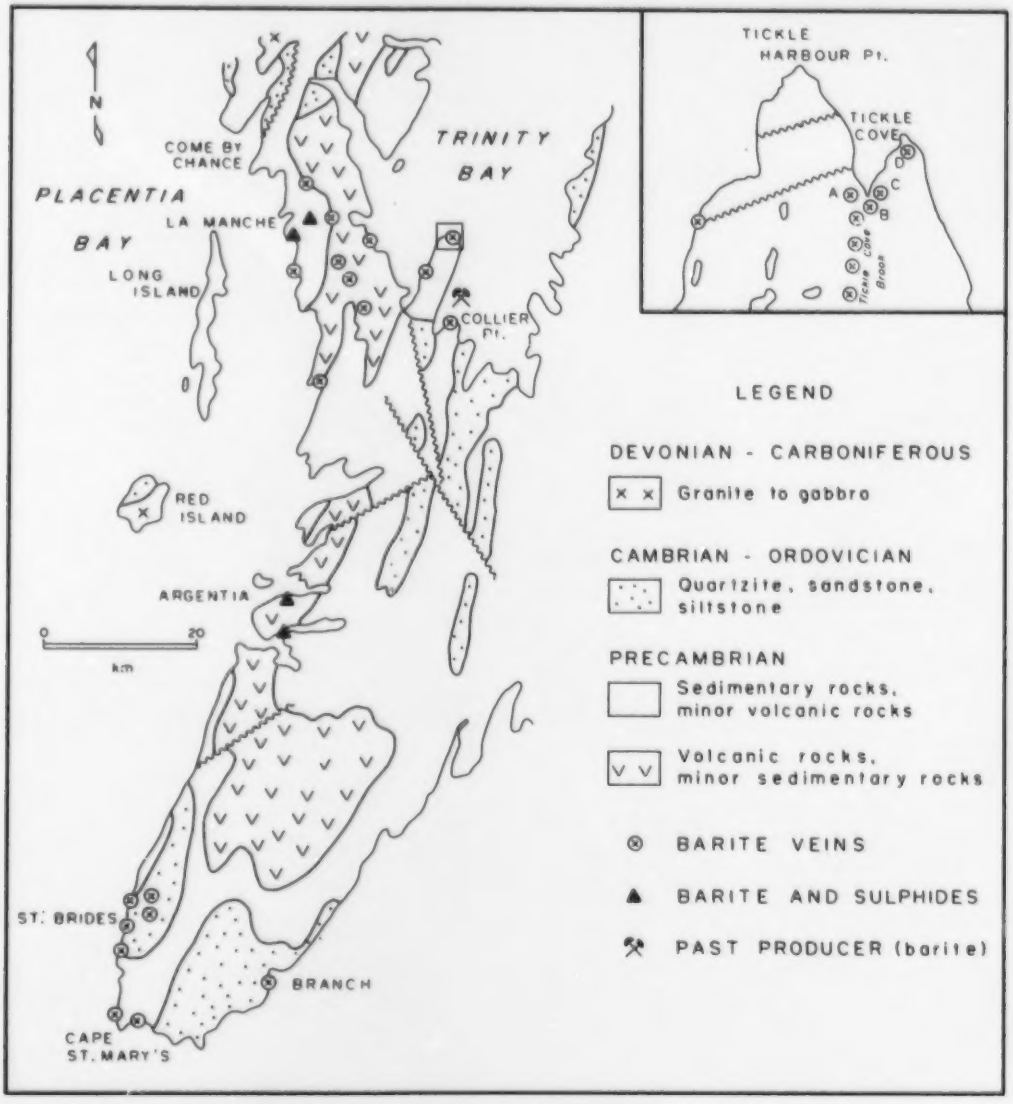


Figure 2. *Barite occurrences on the western Avalon Peninsula.*

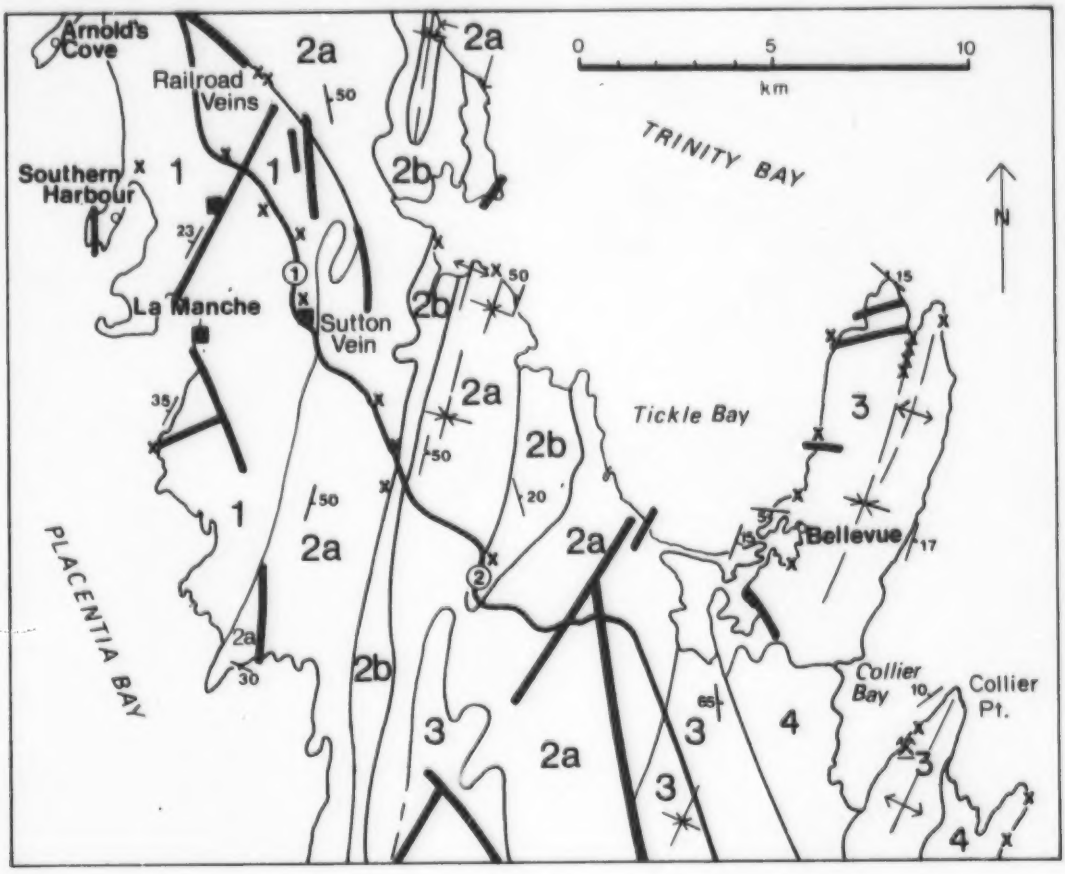
silty layers in grey arkose. The arkoses are commonly crossbedded in the upper part of the formation.

South of Bellevue Peninsula and west of Chapel Arm, the area is underlain by quartzite of the Random Formation and Lower Cambrian red and green shales and nodular limestone.

The structure of the Avalon Isthmus is dominated by a complex system of tear and thrust faults, and large open, gently plunging (north-northeast or south-southwest) folds having moderately dipping limbs. The compressive event, which produced these features, is generally ascribed to the Acadian Orogeny of Devonian age (Williams *et al.*, 1974). An older Precambrian deformation resulted in a number of high-angle faults having vertical displacements reaching several thousand metres (McCartney, 1967). These faults, which generally trend northeast-southwest and northwest-southeast, are usually well exposed in coastal cliffs; others are recognized by a combination of discontinuous structural and stratigraphic units. Some are reflected, topographically, by the shapes and orientations of valleys and ponds and other surface features. Others form pronounced linears, which are easily discernible on air photographs.

Barite Veins and their Origins

More than 40 separate occurrences of barite have been documented on the Avalon Isthmus and along the western shore of Placentia Bay with the greatest concentration occurring in the Isthmus area itself (Figure 3). The barite occurs in veins, which cut strata of all ages, including the



LEGEND

LOWER CAMBRIAN

4 Sedimentary rocks

UPPER PROTEROZOIC

3 Musgravetown Group sedimentary rocks

2 Bull Arm Group: 2a, intermediate volcanic and associated sedimentary rocks; 2b, felsic volcanic and associated sedimentary rocks

1 Connecting Point Group sedimentary rocks

SYMBOLS

Fault
Barite occurrences
Barite and sulphides
Trans Canada Highway
Post producer (barite)

Figure 3. *Geology of the Avalon Isthmus showing the locations of barite veins.*

Late Precambrian Connecting Point Group and the various Early Cambrian formations. They possess remarkably similar characteristics throughout the area. The dominant colours are red and salmon-pink due to the presence of very minute quantities of iron. The barite occurs as aggregates of coarse bladed crystals, the faces of which are up to 5 cm in length. Contact with the host rocks are usually sharp with little or no visible alteration of the rock. Joints near the veins are commonly filled with barite. Quartz and/or calcite are usually associated with the barite. The veins are rarely over a metre thick, averaging considerably less. The Collier Point vein has the greatest documented thickness measuring almost 3 m at one point along its strike.

Barite occurs as a late mineral in the La Manche galena–calcite vein near Southern Harbour and as a minor gangue mineral at the Silver Cliff lead–zinc–silver vein near Argentia (Chute, 1939). In 1982, a lead–barite vein

discovered near Little Southern Harbour by a Newfoundland Department of Mines and Energy stream-sediment sampling crew, contains pods and stringers of barite, galena, calcite and silver in a northeast trending fracture zone (Howse and Collins, 1984).

Barite is the least soluble and most common of the alkaline earth sulphates (i.e., barite, celestite, anhydride) in hydrothermal systems. As measured by Blount (1977), and illustrated in Figure 4, the solubility of barite is enhanced both by increasing fluid pressures and increasing concentrations of NaCl. Figure 4 also shows that an increase in salinity shifts the peak barite solubility to higher temperatures. Thus barite can precipitate during the cooling and release of pressure that accompanies fluid migration along a conduit toward the surface. A sudden drop in the salinity of the fluid (i.e., through mixing of fluids) could also result in the precipitation of barite.

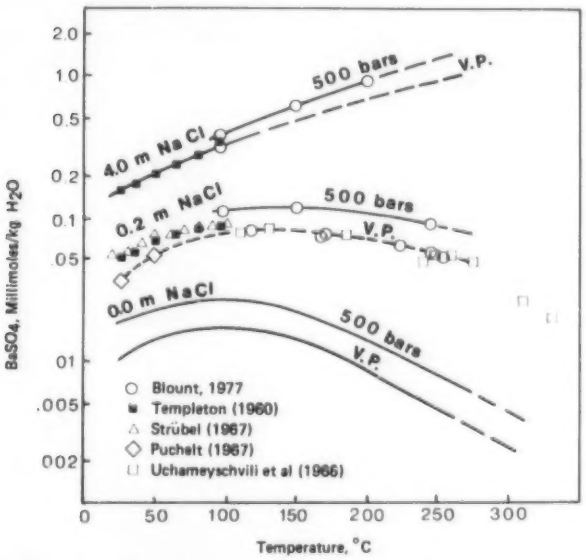


Figure 4. *Graph showing the solubility of barite in water; 0.2 M NaCl along the vapour pressure (VP) curve and at a pressure of 500 bars (from Blount, 1977).*

The origin of the fluids, from which the barite veins and possibly the sulphide-bearing Silver Cliff and La Manche veins precipitated, is as yet unresolved. Granitoid rocks outcrop on several islands in Placentia Bay, such as Red Island and the Ragged Islands. The granitic rocks of Fox Island are within 7 km of the Silver Cliff vein and it is possible that heat and/or fluid components were supplied to the Avalon barite veins by the intrusion of these plutons.

It is unlikely that magmatic hydrothermal fluids contain any significant amount of barium. This presumably is due to the tendency of the Ba^{2+} cation to follow the K^{+} cation into the structures of biotite and alkali feldspars, and therefore not to be available for exsolution into a magmatic aqueous phase. A more likely source for Ba is connate fluids, which have removed Ba from biotite and alkali feldspar of the host rock. In the area of the veins, the Late Precambrian (Hadrynian) Connecting Point Group sediments provide such a source rock. Perhaps significantly, each of these rock units host barite veins. Barium is a common component of connate fluids in sedimentary basins and has been measured at up to 6 000 g/t in such fluids (Hanor, 1979).

Maloney (1991) studied stable isotopes and fluid inclusions of the various phases present in a number of veins on the western Avalon Peninsula. Temperature data obtained by homogenizing fluid inclusions in quartz crystals associated with barite, indicates minimum temperatures of 100 to 200°C for the fluids that precipitated quartz. However, one sample of quartz, from the Silver Cliff vein, yielded homogenization temperatures in the range of 300 to 360°C. Such high temperatures indicate magmatic involvement, at least for the Silver Cliff vein.

The following are descriptions of some significant barite veins in the Avalon Isthmus.

Collier Point Barite Vein

Location and History. The Collier Point barite vein is located 1.4 km south of Collier Point on the north side of the Avalon Isthmus. It is situated at tidewater, and within 10 km of the Trans-Canada Highway via Route 201.

The vein was first worked in the period 1902-1904, when the Collier Cove Barite Company developed the deposit by an open-cut and a 40 foot (12 m) shaft from which a 100 foot (30 m) drift was run. About 5 000 tonnes of barite were produced (Howley and Murray, 1918).

The deposit was investigated by Toronto based mining interests in 1951. They concluded that the deposit was too small to be competitive as a supplier of drilling mud, but that it might have potential as a producer of pure white barite if the salmon-pink variety could be bleached. Bleaching tests were carried out by the same group with successful results (Carr, 1958), but nothing further was done.

McCartney (1967), who examined and sampled the vein in 1958, suggested the barite might be suitable for use as heavy aggregate for concrete in coating underwater pipes and for radiation shielding.

McArthur (1973) re-examined and sampled the vein and noted the deposit represented a very small source of high-grade barite.

In 1980, J. Tyler Mining Limited built a road to the deposit and extracted approximately 9 000 tons of barite from an open cut on the vein. The production was sold to Magcobar Dresser Canada Limited and trucked to St. John's for processing into drilling mud.

In 1982, the vein was examined by the author, who noted that a new, but much smaller vein with a strike parallel to

the old vein, had been uncovered by road construction about 100 m south of the old mine adit. The old vein was measured and chip sampled at regular intervals along its strike. At that time, trenching and stripping had exposed the vein along a continuous strike length of about 600 m. This part of the vein, which averaged less than 1 m in thickness, indicates the vein is pinching along its southward strike.

The vein was intermittently worked in the early 1980's with nearly all of the production going to offshore drilling fluid companies based in St. John's. A small amount was used as a filler in paints produced by the Standard Manufacturing Company in St. John's.

Description. The host rock to the Collier Point Vein is grey-green arkose of the upper part of Late Precambrian Heart's Desire Formation. The beds strike 035 to 070°E and dip to the northwest at 25°. The rocks have a purplish cast, and ripple marks and cross-bedding are common.

The vein strikes 160° and is approximately vertical. It consists of an aggregate of coarse-bladed barite having crystal faces up to 5 cm in length. Most of the barite is salmon-pink in colour but white varieties (probably less than 25 percent) also occur. The vein has been exposed by stripping for more than 600 m inland along strike showing thicknesses up to 1 m. This indicates a marked decrease in the vein's thickness along strike but it could also indicate a tendency for the vein to widen at depth since there is about a 60 m difference in elevation between the shoreline section, which is the widest part of the vein, and the top of the hill which has the thinnest exposed width. A cross section of the vein exposed in the face of an open cut 100 m from the shore line (Plate 1) shows a complex highly digitized vertically dipping structure. The widest section of barite, near the centre of the 4-m-high face measures 1.2 m at its widest point. However, smaller subparallel veins of barite (ranging in thickness from 1 to 30 cm), occurred on both sides of the main body of the vein, comprising a total-mineralized-zone, about 6 m wide. The accumulated percentage of barite in this zone, apart from the main body of the vein, was probably less than 10 percent. The host arkosic sandstone is highly fractured and jointed with thin films of barite occurring along the joint surfaces. The vein was traced a farther 100 m southward along its strike, at which point it had decreased in thickness down to a minimun 40 cm.

In 1982, during road construction (Plate 2), a new barite vein, located about 150 m east of the old vein was uncovered. It parallels the old vein, dips vertically and is traceable along strike for about 100 m. It has a maximum width of 45 cm near the road and pinches to 15 cm along strike. Representative chip samples of this new vein averaged 93.40 percent $BaSO_4$ (Table 4).

Reserves. There are no accurate ore reserve estimates available for the Collier Point barite deposit because no serious attempt has been made to delineate the subsurface dimensions of the vein. The tendency of the vein to pinch-and-swell further complicates the picture and suggests pockets

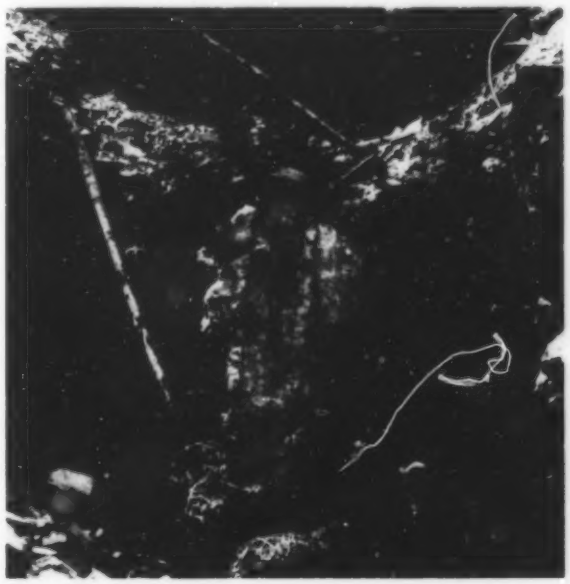


Plate 1. *Collier Point barite vein looking south along its strike.*

Plate 2. *New vein, Collier Point.*

of barite may be present, which could change the estimate. However, the exposed strike length on the surface, and underground observations suggest there probably are at least 20 000 tonnes. Table 6 shows the analyses of samples that have been taken from the vein. The grades, which average between 92 and 93 percent $BaSO_4$, are below the normal minimum grades used in chemical industries and shows that the ore would require upgrading for these purposes. Collier Point barite meets the specifications for oil-well drilling muds and nearly all the production has been for this use. Other

Table 6. Assay analyses of barite samples from the Collier Point vein

Sample No.	Reference	Remarks	$BaSO_4$	$SrSO_4$	SiO_2	CaO	Fe_2O_3
AH-82-38	Howse (1982)	composite of chips taken across width of vein; 100 m from shore	93.51	2.93	2.08	0.01	0.06
AH-82-39	Howse (1982)	composite of chips taken across width of vein (40 cm); 180 m from shore	93.14	3.46	1.30	0.01	0.04
AH-82-40	Howse (1982)	composite of chips taken across vein (30 cm); 280 m from shore	93.72	2.20	1.83	0.01	0.05
AH-82-41	Howse (1982)	composite of chips taken across width of vein (105 cm); 350 m from shore	93.27	3.36	1.51	0.01	0.06
AH-82-42	Howse (1982)	composite of chips taken across width of vein (100 cm); 600 m from shore	91.82	6.19	1.18	0.01	0.02
AH-83-1	Howse (1983)	chip sample across west limb of new vein	91.32	3.63	1.45	0.01	-
AH-83-2	Howse (1983)	chip across east limb (30 cm) of new vein	96.49	1.56	1.68	0.01	-
AH-83-4	Howse (1983)	representative chip sample of white barite taken 300 m from shore	97.71	2.24	4.03	0.02	-
AH-83-5	Howse (1983)	chip sample from south end of vein	94.21	2.23	-	0.02	-
JGM-72-8(1)	McArthur (1972)	grab sample from dump near the old mine workings (3.9 bulk specific gravity)	95.93	1.49	-	-	-
JGM-72-8(2)	McArthur (1972)	chip sample–predominantly white, coarse barite (bulk specific gravity 4.4)	90.59	6.49	-	-	-
MB-54-1	McCartney (1957)	representative sample from old open cut	93.63	4.14	-	0.10	-
MB-54-2	McCartney (1957)	representative sample from old open cut	92.97	2.95	-	0.43	-

potential uses for the barite include aggregate in high-density concrete and as a filler in such products as paint, rubber and carpet backing.

Tickle Cove Barite Veins

A zone of generally north trending, steeply dipping barite veins are found in and around Tickle Cove near the northern tip of Bellevue Peninsula in southern Trinity Bay (Howse and French, 1983) (Figure 3). Access to the area is difficult, requiring a traverse of several kilometres through difficult terrane. The area is also accessible by boat from one of the nearby communities. However, the exposed location of Tickle Cove makes boat landings difficult.

The barite mineralization (associated with quartz and calcite) occurs as fault-and-fracture fillings in a green arkosic crossbedded sandstone containing grey silty lenses. The host rocks are part of the Late Precambrian Heart's Desire Formation. The veins appear to be localized along or near the areas of a synclinal structure mapped by McCartney (1956).

The following is a description of the barite veins in Tickle Cove going from west to east:

VEIN A– This pink and white barite vein is exposed in a 4.5 m cliff in the eastern side of the cove. The vein has a maximum width of 30 cm at the top pinching to 3 cm at the base of the cliff. The host rock is a highly fractured green crossbedded arkose having grey silty lenses. The vein strikes 180° and dips 80°W. On the vein's hanging-wall side, narrow veinlets of barite intersect the main vein at acute angles. Calcite and minor quartz are associated with the barite. The veins appear to be localized along a steeply dipping fault structure, which cuts across the gently (southward) dipping sandstone beds.

VEIN B– The vein consists of pink- and white-bladed crystals of barite and calcite exposed in a 4 m cliff (Plate 3). The vein dips vertically, and can be traced inland (190°) for about 8 m before it is obscured by cobbles and boulders. It maintains a consistent 15 cm thickness and contacts with its arkosic host are very sharp.

VEIN C– This vein, 70 cm wide at beach level, strikes 020° and dips 80°W (Plate 4). It consists of pink and white barite (some in bladed crystal form), calcite and quartz. The vein, which narrows to about 10 cm at top of a 9 m cliff, occurs in flat lying green arkose, which is highly fractured at the footwall contact. The hanging wall is much less disturbed and contains narrow stringers of barite, which parallel the main vein. What appears to be a northward expression of the barite–quartz vein structure was traced northward beneath the waters of the cove for several metres. A sample of this submarine zone shows a dendritic pattern of narrow barite and quartz veinlets (average 1 cm wide) giving the host arkosic sandstone a brecciated appearance.

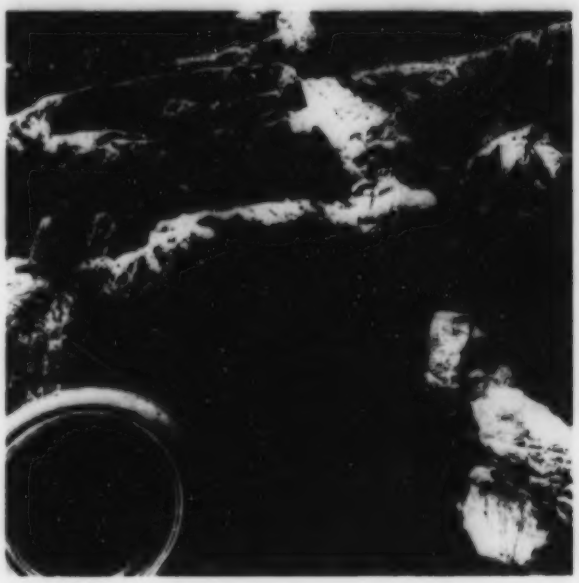


Plate 3. *Vein B, Tickle Cove, Bellevue Peninsula.*

Plate 4. *Vein C, Tickle Cove, Bellevue Peninsula.*

A zone of 8, narrow, barite veins occurs in the extreme western side of the cove. The veins vary from 1 to 6 cm wide averaging 2.5 cm. The veins strike about 240° and dip vertically. A northeast striking fault marks the northwest limit of barite mineralization in this area of Tickle Cove.

VEIN D– This vein was noted by McCartney (1967) and was later described by McArthur (1972). The vein, both ends of which are exposed, is precariously located along a narrow neck of land at the extreme northeast side of Tickle Cove. The vein consists of barite, quartz, and chlorite, and occurs at the eastern extremity of a fault zone, which forms a prominent linear across the tip of the Bellevue Peninsula trending N 70°E. The vein varies in thickness from 2.1 m at the base of a 15 m cliff, to 1 m near the top. The barite tends to be concentrated on both sides of the vein, and makes up approximately 33 percent of vein constituents.

Tickle Cove Brook Barite Veins

Several barite–quartz veins along with abundant similar float were discovered by a Department of Mines and Energy stream-sediment sampling crew, immediately south of Tickle Cove in the bed of a small brook that flows northward into the cove (Howse and Collins, 1984). The veins, which pinch and swell from a few centimetres to more than 100 cm in thickness, are sporadically exposed along a 1 200 m length of the stream. In some instances, it seems quite likely that the same veins are repeatedly exposed. These barite occurrences appear to be part of the generally north-south trending vein system exposed in Tickle Cove. The veins, which dip nearly vertically and strike from 0 to 20°, contain pink and white barite with quartz. The veins cut grey-black siltstone of the Heart's Desire Formation. Analyses of chip samples showed the $BaSO_4$ content of the veins ranges from 41 to 93 percent (Table 7).

Railroad Rockcut Barite Veins

A number of barite veins, ranging in width up to 30 cm, are exposed in the face of two rockcuts on the main CN railway line (now abandoned), about 1 km east Jack's Pond Provincial Park. The veins occur in highly sheared sediments of the Precambrian Connecting Point Group near their contact with the overlying Bull Arm Formation.

The following is a description of mineralization in the two rockcuts.

South Rockcut

A pink and white vein of barite, mainly of coarse-bladed crystal aggregates, is exposed in the west face of the cut (Plate 5). The vertically dipping vein strikes 040° and has a maximum exposed width of about 25 cm at the centre of the 4 m high face. Near the bottom, the vein splits into a number of thinner veins, the thickest of which range from 4 to 10 cm. A number of subparallel offshoots ranging up to 4 cm in width are located near the middle of the cut. The vein is exposed on top of the rock cut for 2 m along strike but is obscured by overburden beyond that distance.

North Rockcut

These barite showings are located about 250 m north along the old abandoned CN railway line from the deposits

Table 7: Assay analyses of barite samples from veins on the Bellevue Peninsula, Trinity Bay

Sample No.	Location	Remarks	$BaSO_4$	$SrSO_4$	SiO_2	CaO
1. AH-82-50	Tickle Cove	chips from 30-cm-wide vein of pink and white crystalline barite	92.01	3.54	3.08	0.01
2. AH-82-51	Tickle Cove	chips from 70-cm-wide vein of barite and quartz	88.37	3.43	6.88	0.08
3. CC-83-7	Tickle Cove Brook	chips from vein (barite and quartz) exposed in stream bed	41.55	1.98	46.50	0.41
4. CC-83-11	Tickle Cove Brook	chips from 1-m-wide vein exposed in brook	93.91	3.68	4.32	0.02
5. CC-83-12	Tickle Cove Brook	chip samples from barite–quartz vein	85.99	3.51	10.45	0.02
6. CC-83-14	Tickle Cove Brook	composite chips from barite veins ranging up to 5 cm wide	93.90	3.97	3.81	0.01

Plate 5. *Barite vein exposed in south rockcut on the abandoned CN Railway line, near Jack's Pond.*

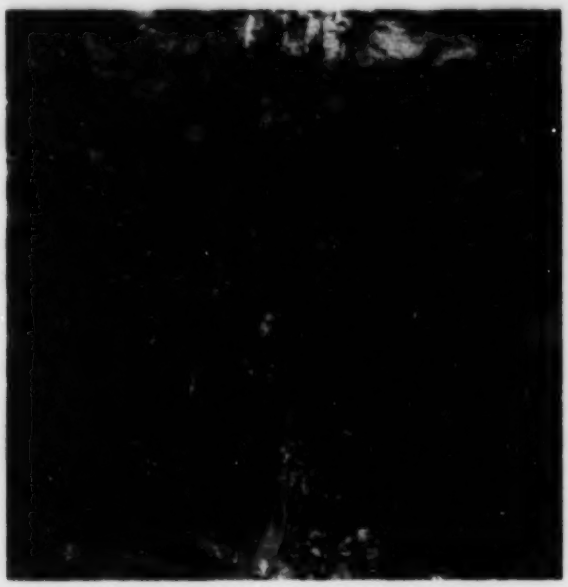


Plate 6. *One of several barite veins exposed in the north rockcut on the abandoned CN Railway line, near Jack's Pond.*

described above. They consist of a zone of narrow veins on the northeast side of the cut. The widest vein is located at the northwest end of the cut and has a maximum width of about 30 cm (Plate 6). It strikes 020° and dips vertically. The other numerous stringers and veinlets, which range in width from less than 1 cm to 7 cm, are irregularly scattered throughout the cut. Thin films of barite also occur on fracture and joint planes in the host rocks.

A chip sample of the 30-cm-wide (maximum) vein assayed 96.80 percent $BaSO_4$, 2.41 percent $SrSO_4$, 0.79 percent CaO and 0.02 percent Fe_2O_3.

Trans-Canada Highway Barite Showings

Several thin barite veins are exposed in rockcuts along a section of the Trans-Canada Highway between the Bellevue access road and Jack's Pond Provincial Park. They occur as fissure fillings in the Connecting Point Group sediments and the overlying Bull Arm volcanic rocks and exhibit characteristics typical of this type of mineralization in the area. The following are descriptions of two of the most prominent barite veins.

Sutton Vein

The Sutton barite vein is exposed in a rockcut on the Trans-Canada Highway about 1 200 m north of the La Manche overpass (Plate 7). Pink and white barite in bladed crystalline and massive forms, comprises veins of variable thickness ranging from approximately 0.6 m at the base of the highway to 5 to 8 cm at the top. The vein strikes 020°, dips vertically and contains minor amounts of calcite and black organic clay at its edges. Joints, which trend 090° to 135°, are coated with barite and calcite close to the vein. Minor amounts of chalcopyrite and galena have also been identified.

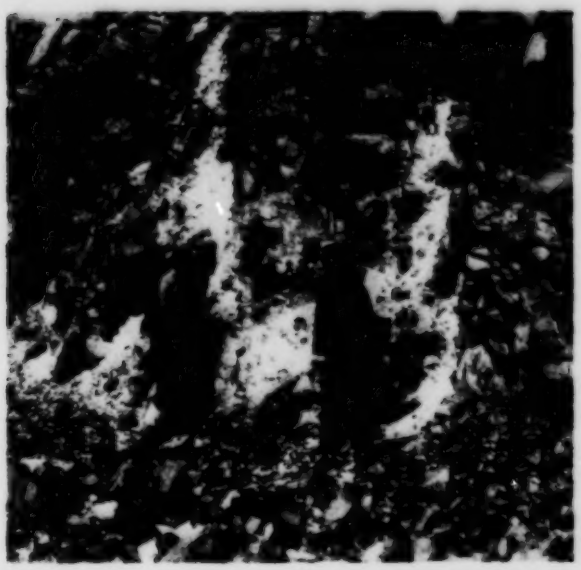


Plate 7. *Sutton barite vein adjacent to the Trans-Canada Highway near the La Manche overpass.*

The vein cuts thin bedded volcanic arenite, siltstone and sandstone of the Connecting Point Group.

Doe Hill Vein

The Doe Hill veins are located on the east side of an abandoned section of the Trans-Canada Highway about 2 km south of the Chance Cove Access Road. Barite veins, varying in thickness from 1 to 30 cm, occur along joints that dip vertically and trend 010 to 030°. Barite also occurs as film on a joint set and attitude of which is 130° to 160° vertical. The veins cannot be traced more than 6 m along strike.

The barite occurs as white and pink crystalline coatings and tabular bladed crystals in veins along the joints. The host rocks are red-pink and green rhyolite of the Bull Arm Formation.

Powerline Veins

Several narrow barite veins occur in close proximity to each other near the Trans-Canada Highway about 2 km south of the Southern Harbour access road. Most of the occurrences are located in a single rockcut on the north side of the highway; none can be traced beyond the face of the cut. At least four zones of northeast trending stringers and veinlets of pink and white barite are located within a 100 m distance. The following are brief descriptions of each zone going from northwest to southeast along the rock cut:

(1) composite vein of barite, quartz, and calcite ranging from 2 to 10 cm in width. The vein strikes 050° east and dips 65° south.

(2) barite veinlets, up to 2 cm wide, attitude 050°/70°S, located approximately 10 m southeast of (1).

(3) pink barite veinlets and associated quartz and calcite up to 10 cm wide, attitude 060°/70°S, located 30 m southeast of (2).

(4) vertically dipping pink barite vein, maximum width 5 cm, attitude 40°/vertical, located 40 m southeast of (3).

Approximately 700 m northeast of the above zones, additional minor barite is exposed in highway rockcuts. Pink and white barite coats joint planes (Plate 8) and fill thin fractures and fissures up to 10 cm wide. The veins are too thin and widely spaced to be of economic interest. All are hosted by strongly fractured sediments of the Connecting Point Group.

Plate 8. *Barite coating joint plane; Avalon Isthmus.*

Little Southern Harbour Lead–Barite Vein

The Little Southern Harbour lead–barite vein is a newly discovered showing (Howse and Collins, 1984) located midway between the Trans-Canada Highway and the east shore of Little Southern Harbour. It is exposed in the bed of a small brook immediately upstream from the water supply reservoir that serves Little Southern Harbour.

The vein has a maximum exposed width of 80 cm but appears to pinch rapidly on both sides of the stream. Barite, calcite and galena occur as pods, blebs, and stringers within the fractured and brecciated host rocks. One such pod about 20 cm in diameter was estimated to contain 60 percent barite and 40 percent galena. The galena occurs mainly as coarse-crystal aggregates in a barite and calcite gangue but isolated

blebs and patches also occur (Plate 9). The vein, which appears to be along a faulted, brecciated zone, strikes 030° and dips vertically. Five grab samples of vein material averaged 19.3 percent barite, 31.9 percent lead and 27.5 g/t silver (Table 8). The vein occurs in fractured and brecciated grey siltstone of the Connecting Point Group.

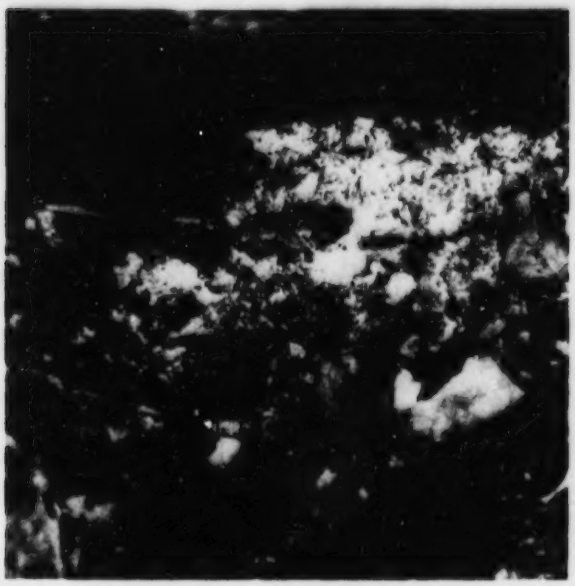


Plate 9. *Little Southern Harbour barite vein; note coarse galena crystal aggregates in barite and calcite.*

Table 8. Assay analyses of samples taken from the Little Southern Harbour barite vein

Sample No.	Ba (%)	Pb (%)	Sr (%)	Ca (%)	Cu (ppm)	Zn (ppm)	Ag (ppm)
14	56.3	<1	1.17	0.02	704	2	1
16	20.6	43.5	0.71	1.32	202	12	26.7
17	3.2	56.8	0.10	4.21	38	14	38.3
20	10.9	52.0	0.31	1.81	50	9	44.1
22	5.8	7.42	0.15	0.47	36	4	27.7

La Manche Lead Mine

There are minor amounts of barite occurring as a late mineral in the galena–calcite vein located at La Manche on the northeast side of Placentia Bay. The abandoned mine workings can be reached by a gravel road branching north from the Little Harbour East Highway about 1 km west of its intersection with the Trans-Canada Highway. The mine, which operated periodically during the last half of the nineteenth century produced about 19 000 tonnes of galena (Howley and Murray, 1918).

The partially collapsed underground workings occupy a linear valley, which apparently marks the trace of a fault zone, along which the vein was injected. The vein is about 600 m long, averages 30 cm wide, strikes 45 to 70° and dips vertically. It consists of scattered grains and aggregates of galena having minor sphalerite and chalcopyrite in a mainly calcite gangue. Minor amounts of barite and quartz are also present.

Barite occurs along irregular fractures and as joint films near the adit entrance on the coast (Plate 10). The vein structure is banded with well-developed comb structure and numerous vugs. Galena is the most abundant mineral and sphalerite is scattered erratically through the vein as discontinuous bands up to 5 cm wide. Chalcopyrite and pyrite are rare, the former occurring as tiny crystals in vugs and disseminations, the latter as cubes adjacent to the vein and interstitial with the chalcopyrite.

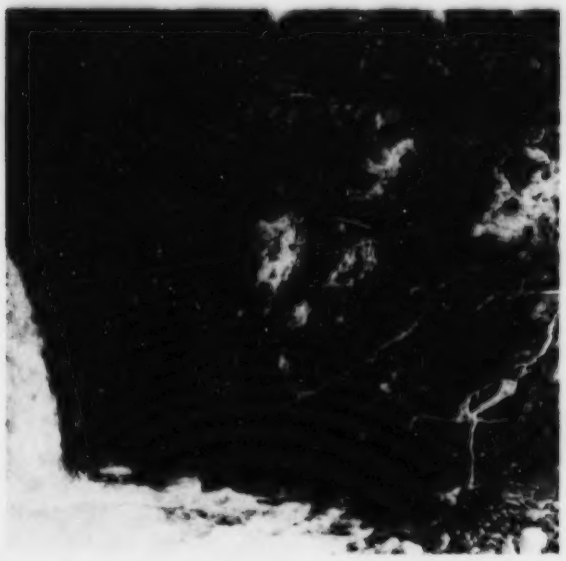


Plate 10. *Barite infilling splay fractures of the main La Manche fault on the shoreline at La Manche, Placentia Bay; note the barricaded entrance to the old lead mine to the left.*

A select sample of pink, coarse barite from the La Manche vein assayed 93.6 percent $BaSO_4$, 3.00 percent $SrSO_4$ and 0.051 percent Hg. The specific gravity is 4.1.

St. Bride's–Cape St. Mary's Barite Deposits

A number of barite veins are exposed on the coast in the St. Bride's area of the southwestern Avalon Peninsula (Figure 2). In 1983, the Department of Mines and Energy carried out a reconnaissance geochemical stream-sediment survey over a 110 km² area between Cape St. Mary's and Angels Cove. The project objective was to identify inland areas with good potential for barite and to stimulate exploration for these deposits. Several new occurrences of barite were discovered and the results of the survey have been released (Howse *et al.*, 1984b).

Figure 5. *Geology of the Cape St. Mary's Peninsula showing location of barite veins (geology after Fletcher, 1972).*

The following section briefly summarizes the geology and describes the barite deposits in the St. Brides–Cape St. Mary's area.

Geology

The Cape St. Mary's Peninsula was mapped over a four year period by Fletcher (1972). His 1:50 000-scale map of the southwestern Avalon was the first comprehensive geological map of the region. Other geological studies relating to the area have been carried out by O'Driscoll and King (1985) and King (1988). The region comprises a continuous Upper Cambrian to Upppermost Precambrian sequence, which is divided into three groups–Musgravetown (Hadrynian) arkoses, grits, shales and volcanic rocks; Adeyton (Lower to Middle Cambrian) red and green calcareous mudstone; and Harcourt (Middle to Upper Cambrian) grey shales and sandstones (Figure 5).

The St. Bride's–Cape St. Mary's area is located on the western side of the Cape St. Mary's Peninsula. Fluviatile arkoses, grits, shales and volcanic rocks of the Musgravetown

Group underlie much of the project area. These rocks were divided by Fletcher (1972) into six formations—Bull Arm, Brierly Cove, Lears Cove, Northern Head, Cross Point and Random. O'Driscoll and King (1985) and King (1988) correlated Fletcher's formations with those to the north, retaining the names Bull Arm and Random.

The region contains large open folds and flexures with dips rarely more than 60°. These folds are aligned in a northeasterly direction. Generally, the older exposed Musgravetown rocks are less deformed and form concentric bands around broad, open-crested anticlines.

Most of the documented faults in the area are exposed in coastal cliffs, and their inward extensions can be detected on aerial photographs or through field observations. The main faults are related to stresses developed during folding. These tear faults have mainly vertical dips and persist for several kilometres along a usually straight trend.

Barite Veins

Cross Point Vein

The location of Cross Point Vein (Plate 11) has been known for over a century. It was first mentioned by Milne (1874) and later by Howley and Murray (1918). Reports dealing with Newfoundland's minerals resources by Baird and Snelgrove (1953) and Carr (1958) both contain descriptions of the deposit. The renewed interest in barite sparked by offshore petroleum exploration led to further investigations of the deposit by McArthur (1972) and Howse and French (1983).

The vein is located about 700 m southeast of Cross Point on the eastern side of Placentia Bay where a cross-section of the vein is exposed in 10- to 15-m-high sea cliffs. It consists of white to salmon pink barite occurring as semi-radiating aggregates of thin bladed crystals. Approximately mid-way up the 10 m cliff, the vein attains its maximum width of 1.5 m. At beach level the vein is split into two sections, 0.4 m and 1.0 m wide respectively, forming an N-shaped structure. The two limbs are separated by a 0.7 m section of red shale. The vein strikes 020°E and dips 80°SE although a large part of the N-shaped structure is vertical. At the top of the cliff the barite pinches to a few centimetres and cannot be traced along strike. The host rocks are gently dipping Eocambrian red shales siltstones and impure quartzite. In a 15-m-wide zone, immediately west of the vein, these rocks are tightly folded into isoclinal and recumbent folds. The country rock near the vein is intruded by four diabase dykes that strike northwest and dip steeply northeast. The dykes range up to about 1 m wide. One of the dykes contains a stringer of barite proving the barite is the later intrusion. To the east of the vein there is no evidence of such folding.

Cuslett Vein

The Cuslett (Otterrub) barite vein is located about 500 m north of the community of Cuslett on the east shore of Placentia Bay and is accessible via a 750 m trail, which branches west from Route 100. The pink and white vein consists of well-developed bladed crystals exposed along a 30 m cliff (Plate 12). Its maximum width of 1 m is located about 4 m above low water mark with a minimum width of 6 to 7 cm halfway up the cliff widening to 0.5 m at the top. The vein can be traced for 8 m from low water mark to the base of the cliff. It cannot be traced inland from the top. The vein strikes 052° and dips vertically. The vein cuts pebble conglomerate of the Lower Cambrian Bonavista Formation.

Plate 11. *Cross Point barite vein near St. Bride's, Placentia Bay.*

Plate 12. *Otterrub barite vein near Cuslett, Placentia Bay.*

The wider section of this barite vein has a distinctive banding that is probably a result of growth by repeated opening and filling of the vein fissure (Plate 13). It appears that with each widening of the fissure, individual barite crystals grow on, and nearly perpendicular, to the wall of the structure completely filling it. This process, repeated several times, results in the present width of the vein.

Plate 13. *Cuslett barite vein showing growth bands consisting of coarse, platy crystals.*

Other Barite Occurrences

Other narrow barite veins occur along the coast (Plate 14) in the St. Bride's–Cuslett area and near the Cape St. Mary's lighthouse. During the field work for a stream-sediment survey, several minor occurrences of barite were noted (Howse and Collins, 1984). Float found in a tributary that flows southward into Cuslett Brook was traced to its source, which consists of poorly exposed veins 10 cm wide in red mudstone. Similar barite veining occurs in a roadcut on Route 100 about 500 m west and along strike from the stream occurrence.

J. Maloney (personal communication) reported a narrow barite vein on the coast, approximately 500 m south at the Cross Point vein. Narrow veins generally less than 5 cm wide

Plate 14. *Panoramic view of coastal cliffs near St. Bride's, Placentia Bay; note barite vein in middle of photograph.*

cut flat, gritty sandstone. Diabase dykes, which intrude the sandstone are also cut by the barite veins, as are earlier quartz veins, some of which also contain late barite in vugs. In one 7-cm-wide vein (attitude 012°/90°), coarse white to pink crystals of barite are found on the west side of the vein and fine crystals on the east side.

Greene (1962) mentioned small occurrences of barite on the coast north of Branch and these were re-examined in 1983 (Howse *et al.*, 1984). One vein is located about 200 m south of the main wharf in Branch. It is 6 to 8 cm wide, strikes 100° and dips vertically. The pink and white vein consists of barite and calcite and can be traced for 4 m. Another 5- to 7-cm-wide vein is located on the coast about 1.4 km south of the community near Branch Head. Its attitude is 120°/70°. Green intrusive dykes cut the country rock (red and green mudstone) at approximately the same strike as the veining. Quartz stringers are also common in the dykes. For both of the above barite occurrences, the host rocks are red and green mudstones and have been assigned by Fletcher (1972) to the Middle Cambrian Adeyton Group.

Analyses of chip samples collected from the larger veins in the St. Bride's area (Table 9) averaged more than 95 percent $BaSO_4$ and less than 1 percent SiO_2.

Table 9. Assay analyses of samples from barite veins located near St. Bride's, Placentia Bay

Sample No.	Name	Remarks	$BaSO_4$	$SrSO_2$	SiO_2	CaO	Fe_2O_3
AH-82-35	Cuslett (Otterrub)	chip sample across width of vein	96.99	1.61	0.74	0.01	0.10
AH-82-36	Cross Point	chip sample across width of vein	94.13	3.01	0.82	0.01	0.03
AH-83-6	Cuslett Brook	representative grab sample	96.00	1.98	1.11	0.01	
AH-83-11	Cuslett Brook	representative grab sample	96.00	2.78	0.29	0.01	

BURIN PENINSULA AND FORTUNE BAY BARITE OCCURRENCES

ST. LAWRENCE FLUORSPAR DISTRICT BARITE OCCURRENCES

The 44-year-period of fluorspar mining, which the St. Lawrence area experienced between 1933-78, established that district as one of the world's most important fluorite producers, and indeed Canada's only commercial operation. Some 4.2 million tonnes were produced before production ceased because of economic reasons. In 1987, the mines were again put into production and operations continued until 1991 when poor market conditions again forced the mines to close. Possible future reactivation of the St. Lawrence fluorspar mines raises the question as to whether other commodities can be produced as by-products. One mineral that occurs as gangue in some of the fluorite veins is barite. Although there is a general lack of information on the exact amount of barite contained in the different vein systems, there is a general consensus among researchers who studied the various exploited veins that barite as a gangue mineral comprised a relatively minor proportion of the mineral constituents, probably less than ten percent (Van Alstine, 1948; Williamson, 1956). However, it was also observed that fluorite veins, which occur in the peripheral regions of the St. Lawrence fluorspar district, contain significantly higher proportions of barite. Past assessment work, including diamond drilling, indicate that these outlying veins may contain up to one third or more barite (Smith, 1957).

The Department of Mines and Energy carried out field programs in 1983-84 in the St. Lawrence fluorspar district. The work was aimed at acquiring a better understanding of the area's barite potential and consisted of a vein sampling project and a regional stream-sediment survey (Howse and Collins, 1984).

The following section summarizes the geology and emphasizes the areas fluorite–barite occurrences.

Geology

The Burin Peninsula is mainly underlain by a thick, sequence of Upper Precambrian to Cambrian volcanic and sedimentary rocks that can be traced northeastward to Bonavista Bay and the Avalon Peninsula and has equivalents in the Maritime provinces and the eastern seaboard of the United States. These stratified rocks were intruded during the Middle to Late Palaeozoic by various types of granitoid plutons.

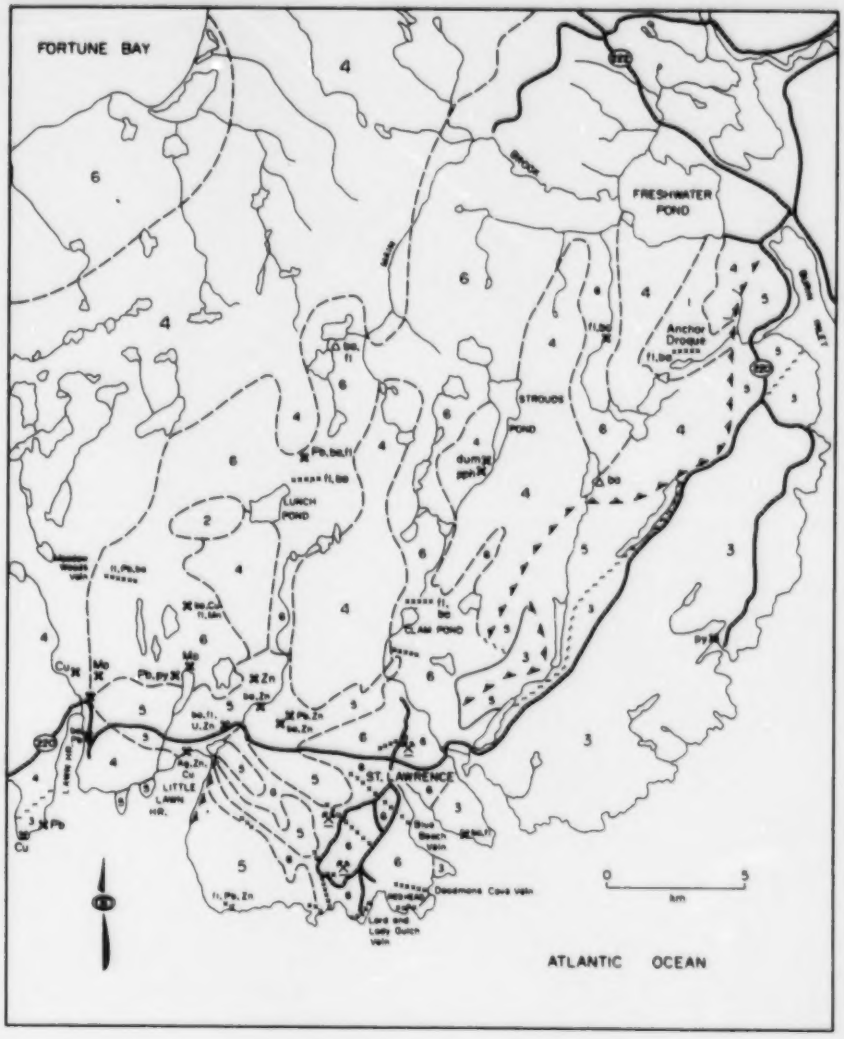
The general geology of the St. Lawrence area, (Figure 6), can best be described in terms of three principal rock associations: (1) Upper Precambrian volcanic and sedimentary rocks of the Burin and Marystown groups, (2) Cambrian fine grained clastic sediments and limestone of the Inlet Group, and (3) the Carboniferous St. Lawrence Granite. These rock units are briefly described below; for more complete descriptions, the reader is referred to Van Alstine (1948); Williamson (1956); O'Brien *et al.*, (1977); and Strong *et al.* (1978).

The oldest rocks in the St. Lawrence area are basaltic pillow lava, aquagene tuff, clastic sediments and gabbro assigned to the Burin Group. A gabbro sill within this sequence has yielded a radiometric (U–Pb in zircon) age of 763 $\pm$ 2 Ma (Krogh, 1982), the oldest date recovered to date from the Burin Peninsula. The Burin Group is locally overlain north of the St. Lawrence area by the Rock Harbour Group, a medium- to coarse-grained clastic sedimentary sequence having a granitoid–silicic volcanic provenance. The younger volcanic rocks in the St. Lawrence area, outcropping to the west and northwest of the Burin Group, are assigned to the Marystown Group, a thick, bimodal basalt–rhyolite flow sequence with intercalated tuff, agglomerate and clastic sediments. The volcanic rocks were, for the most part, erupted subaerially and they form part of a laterally extensive volcanic terrain that can be traced throughout the Burin and Avalon Peninsula.

The youngest stratified rocks in the St. Lawrence area comprise an assemblage of fine grained sandstone, siltstone and shale with interbedded limestone assigned to the Inlet Group. Fossils date this sequence as Early Cambrian; the general characteristics and regional setting of the sediments indicate that they were deposited in a shallow marine environment upon the older volcanic terrain. These sediments are lithologically similar to, and correlative with, numerous small pockets of Lower Cambrian sediments, which outcrop from Fortune Bay north to Bonavista Bay and east to the Avalon Peninsula. They collectively appear to represent the remnants of a blanket of sediments, which were deposited in a shallow sea covering eastern Newfoundland in the Late Precambrian (600 Ma).

The youngest, and in economic terms the most important, geologic unit in the St. Lawrence area is the St. Lawrence Granite, which is genetically responsible for, and in most cases host to, the fluorite mineralization. It is mainly syenitic to alaskitic in composition and, in most exposures, is fine to medium grained, porphyritic to equigranular, and bright red in colour. It is peralkaline (Teng, 1974) and typically consists of quartz (30 to 40 percent), orthoclase (40 to 60 percent), albite (up to 20 percent) and rare ferromagnesian minerals represented principally by riebeckite, aegirine and biotite.

The St. Lawrence Granite intrudes the Burin, Marystown and Inlet groups and, at the present level of exposure, is barely unroofed. Flat contacts with the overlying Inlet Group sediments are exposed in some road- and stream-cuts. Outliers of granite occur in the country rocks for considerable distances away from the main granite exposure, suggesting



LEGEND

CARBONIFEROUS
6 *St. Lawrence Granite*

CAMBRIAN
5 *Inlet Group (clastic sedimentary rocks)*

PRECAMBRIAN
4 *Marystown Group (subaerial volcanics)*
3 *Burin Group (submarine basalts)*

INTRUSIVE ROCKS
2 *Loughlins Hill Pluton (gabbro)*
1 *Anchor Drogue Pluton (granodiorite)*

Abbreviations

ba	*Barite*
dum	*Dumortierite*
fl	*Fluorite*
py	*Pyrite*
pph	*Pyrophyllite*
Cu	*Copper*
Pb	*Lead*
Mn	*Manganese*
Mo	*Molybdenum*
Ag	*Silver*
U	*Uranium*
Zn	*Zinc*

SYMBOLS

Fluorite vein ..... ××××
Mineral occurrence (dumortierite) ..... ⊠dum
Mineralized float ..... △

Figure 6. *Geology of the St. Lawrence area (after Strong* et al., *1976).*

that the roof zone of the pluton is present at shallow depths in the subsurface, well beyond its present surface exposure. The granite has been dated at 334 ± 5 Ma (Bell *et al.*, 1977), by Rb–Sr radiometric age dating.

Mineralization

More than forty individual fluorite veins, varying in length from several metres to over 3 km, have been documented in the St. Lawrence area, although only about half of these are sufficiently large to be of economic interest. Excellent detailed descriptions of many of these veins can be found in Kauffman (1936), Van Alstine (1948), Williamson (1956) and Smith (1957). The following sections briefly review the general characteristics of fluorite mineralization in the St. Lawrence area and focus on some of the more important veins, which lie within the former ALCAN properties.

Most of the fluorite-bearing veins in the St. Lawrence area are hosted by the St. Lawrence Granite and its outliers and occur within a 6.5 km radius, west and north of the town (Figure 6). Two major groups of mineralized veins have been recognized.

A set of high-grade veins strikes from 070° to 110°. These veins grade up to 95 percent CaF_2 and are free-milling, containing fluorite and rare inclusions of granitic wall rock but almost no gangue minerals.

A set of low-grade veins generally strikes from 140 to 160°. These veins grade up to 70 percent CaF_2 but may contain more than 50 percent quartz, calcite and horses of country rock, where the vein systems form networks rather than a single vein. The low-grade veins range up to

2.5 km in length and, while averaging 7 m wide, locally attain a width of 30 m.

All veins in the St. Lawrence area show a strong tendency to pinch and swell, in both horizontal and vertical directions, producing a series of lenticular orebodies within each vein system.

The structures, which contain the mineralization can, in some instances, be followed beyond the St. Lawrence Granite into the adjacent sedimentary rocks (e.g., Blue Beach and Director veins). This most commonly occurs where the granite intrudes fine grained sediments of the Inlet Group. However, the latter appear to have been unable to maintain sufficiently open fractures to allow substantial mineralization to take place. The veins, which cross this lithologic boundary, quickly die out in the surrounding sediments.

Most veins are characterized by finely laminated fluorite at and near the margins and by prominent colour banding of the fluorite throughout the veins, parallel to the vein walls. This, as well as the abundance of open vugs and slickensided surfaces within the veins and the common preserve of comb and ribbon structures, suggest that the mineralization formed during repeated openings of the fissures. Williamson (1956) and most subsequent authors have felt that this distensional regime probably resulted from contraction of the granite body during cooling.

The specific features of the east-west, high-grade veins are relatively simple. The veins usually consist of coarsely crystalline, massive fluorite which commonly fills the veins. Wall-rock boundaries are sharp. Large vugs up to 30 m long contain spectacular intergrowths of fluorite crystals in some cases.

The north-south, low-grade veins tend to be more complex structures and the ores in them more varied. Besides the massive, crystalline fluorite, which in these veins is most common near the walls, two or more complex ore types are found, referred to as 'blastonite' and 'nodular ore'.

Blastonite is a local descriptive term referring to brecciated fluorite in a matrix of microcrystalline quartz and fluorite. The relative proportions of quartz and fluorite in this material are highly variable and the ore may comprise up to 85 percent of either component. In some places, blastonite grades into dense, white quartz; in such a situation, a typical cross-section through the vein would exhibit the sequence: wall rock–massive fluorite–massive white quartz–blastonite–narrow fluorite–wall rock (Williamson, 1956). The blastonite appears to have formed by post-ore movement along fissures, which brecciated pre-existing fluorite and in so doing, provided channels for later quartz- and fluorite-rich solutions that deposited the matrix.

Nodular ore is best developed in the large, north-south veins (e.g., Director or Blue Beach veins) and consists of rounded nodules of rhythmically banded fluorite and calcite having a nucleus composed of slate, granite or older fluorite. The successive bands vary in colour and texture and appear to have formed by precipitation from alternating calcite- and fluorite-rich solutions (Van Alstine, 1948). The nodules were cemented by a fine grained matrix consisting of variable proportions of calcite and fluorite. Nodular material ranges from sub-ore to very high grades.

Mineralogy

Fluorite in all the veins range from massive anhedral growths to coarsely crystalline cubic and octahedral crystals. The colour of the fluorite is very variable, both from vein to vein and within the same vein. Williamson (1956) noted that the most common colours are pale blue, green, grey, yellow, red, purple, white and colourless, and that colour banding parallel to the vein walls is particularly characteristic of the high-grade veins. Further, Williamson (1956) noted that the deep purple variety appears to be the earliest type as it commonly occurs in contact with the wall rocks and also is found lining miarolitic cavities in the country rock not associated with any vein structures.

The principal gangue minerals are quartz, calcite, sulphides and barite associated with minor amounts of secondary iron, copper and manganese minerals. Quartz is the most important of these and occurs in three principal forms: (1) as part of the matrix to blastonite and as white silica masses associated with blastonite, (2) as small euhedral crystals lining vugs in the veins, and (3) associated with feldspar in granite inclusions in the veins. Calcite is the second most abundant gangue mineral and constitutes up to 10 percent of some orebodies in the north-south veins. Calcite is present in both high- and low-grade veins, although it is relatively more abundant in the latter. It forms an important constituent of the nodular ore, both in nodules and matrix, and is also found in coarse bands parallel to the vein margin alternating with fluorspar. Minor amounts are also present as disseminated crystals and tiny veinlets. Calcite deposition appears to have been both contemporaneous with and slightly later than most of the fluorite deposition.

Primary sulphide minerals, principally pyrite, chalcopyrite, galena and sphalerite, commonly compose less than 1 percent of the veins. Sulphides tend to be more prevalent in veins near the granite margins than in the interior of the pluton and locally may compose 5 percent of the vein material. Galena is the most abundant sulphide mineral and is commonly argentiferous. It is followed, in abundance, by red sphalerite. Locally, chalcopyrite is present as coarse, disseminated crystals imbedded in fluorite, mainly in the Blue Beach and Director veins; pyrite is a common constituent of the sulphide assemblage in the Director vein but is rare elsewhere. Barite is fairly widespread but is commonly only a minor gangue mineral. In the past, barite was considered a waste product and thus no real effort was made to determine the exact amount of barite contained in the different exploited veins. Diamond-drilling core sections, for example, were not assayed for $BaSO_4$ although the descriptive logs frequently noted the presence of barite. Van Alstine (1948) observed that

barite was not a very common gangue mineral of the fluorspar veins although he did note that in sections of some veins it formed nearly 10 percent of the thickness of the vein. He observed that the barite was white or pale pink and occurred as coarse crystals or platy masses intergrown with fluorite cubes and coating them. He observed barite in the Blue Beach, Tarefare, Little Salt Cove and valley veins. Williamson (1956) observed the presence of barite in the iron springs and canal veins as honey yellow tabular crystals both intimately intergrown with fluorite and as growths on the surface of cubes. He also observed platy aggregates of barite intergrown with fluorite at Lord and Lady Gulch, Meadow Woods and in veins along the coast between Chambers Head and Salt Cove. Collins (1984) systematically chip-sampled most of the exposed fluorite veins in the St. Lawrence area and showed barite to be a relatively common gangue mineral in many of the veins including Tarefare, Blue Beach and Big Meadow Woods. The author noted the presence of barite in an exposed section of the Tarefare vein (Plate 15).

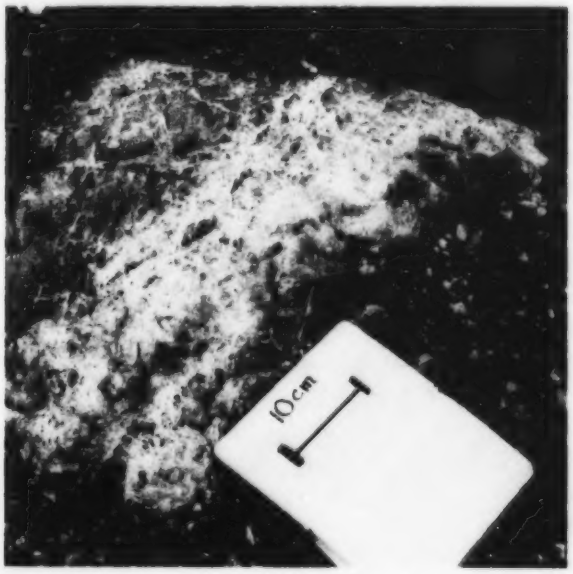


Plate 15. *Barite associated with fluorite, Tarefare vein system, St. Lawrence.*

Barite in Outlying Veins

Fluorite veins that occur in the peripheral regions of the St. Lawrence fluorspar district are known to contain significantly higher proportions of barite than those past producers, which are all centred within 3 km of St. Lawrence. Veins of fluorite, with an associated barite content ranging up to 20 percent, occur in a number of widely scattered locations north of Lawn and St. Lawrence. This group, which includes the Meadow Woods, Anchor Drogue, Lunch Pond, Devils Kitchen, Filt Hill and Clam Pond veins, were collectively referred to as 'outlying' veins by Smith (1957) because of their location away from the main concentration of veins. The Big Meadow Woods Extension discovered by D.S. Robertson Associates Limited (1972) and the Lawn Barite Vein uncovered by road construction (1982) are included with these deposits.

Meadow Woods Vein

The Meadow Woods vein (Figure 7) is by far the most important of the outlying veins of the district. Discovered in 1944 by Aloysius Molloy and Louis Kelley, about 4 km north of Lawn, it was traced by early workers for approximately 600 m along its east-west strike. The width of the vein decreases eastward, averaging 3.6 m for 180 m, then 1.8 m for the next 180 m and gradually narrowing to about 1.2 m for the remaining strike length.

In the 1950's, Newfoundland Fluorspar Limited sank a 12.2 m shaft into the vein to learn more about its characteristics at depth, and to establish the relative proportions of the different minerals (fluorite, barite, galena). Table 10 below shows the analytical results of samples taken during this work.

Fluorite and barite were found to be mixed intimately but the galena was concentrated in a 15-cm-wide band in the vein.

Newfoundland Fluorspar Ltd. (1976) drilled eleven holes along the vein structure. Drilling confirmed the high fluorite content of the vein but the core was not assayed for $BaSO_4$.

The Meadow Woods trenches were examined by this author in 1983. Rubble in the trenches consists of blocks of barite-rich, white fluorite and pink and salmon-pink barite. The barite occurs as fine-grained bands and crystal aggregates with fluorite and quartz. Malachite was also observed. Barite is estimated to comprise up to 20 percent of the vein. Smith (1957) concluded from his examination of the vein, as exposed in the trenches, that it contained barite sufficient to make up one-quarter to one-third run of the iron ore. The author's observations and the analytical results of representative samples collected from the vein lend support to that view.

Meadow Woods–East Extension Veins

Extensive barite–fluorite float was also noted in trenches about 6 km northeast of Lawn (Figure 7). The barite displays pink and white banding and has a bladed crystal texture. White, purple and green varieties of fluorite were noted. Minor galena and pyrite are associated with the barite and fluorite. The trenches were excavated by D.S. Robertson Associates Limited (1972), while exploring a series of airborne-derived VLF anomalies in the area. The anomalies trend toward the Meadow Woods vein, some 2.5 km to the west. These anomalies were tested by a series of diamond drill holes in the immediate area of the trenches. Hole 72-4 (45°) intersected extensive barite–fluorite mineralization in granite from 13.9 m to 46.0 m. The hole log describes a system of parallel veins, up to 1.3 m thick, occurring in fractured, hematized, kaolinized, granite. Barite and fluorite occur in brecciated and silicified zones; galena was also noted. In most

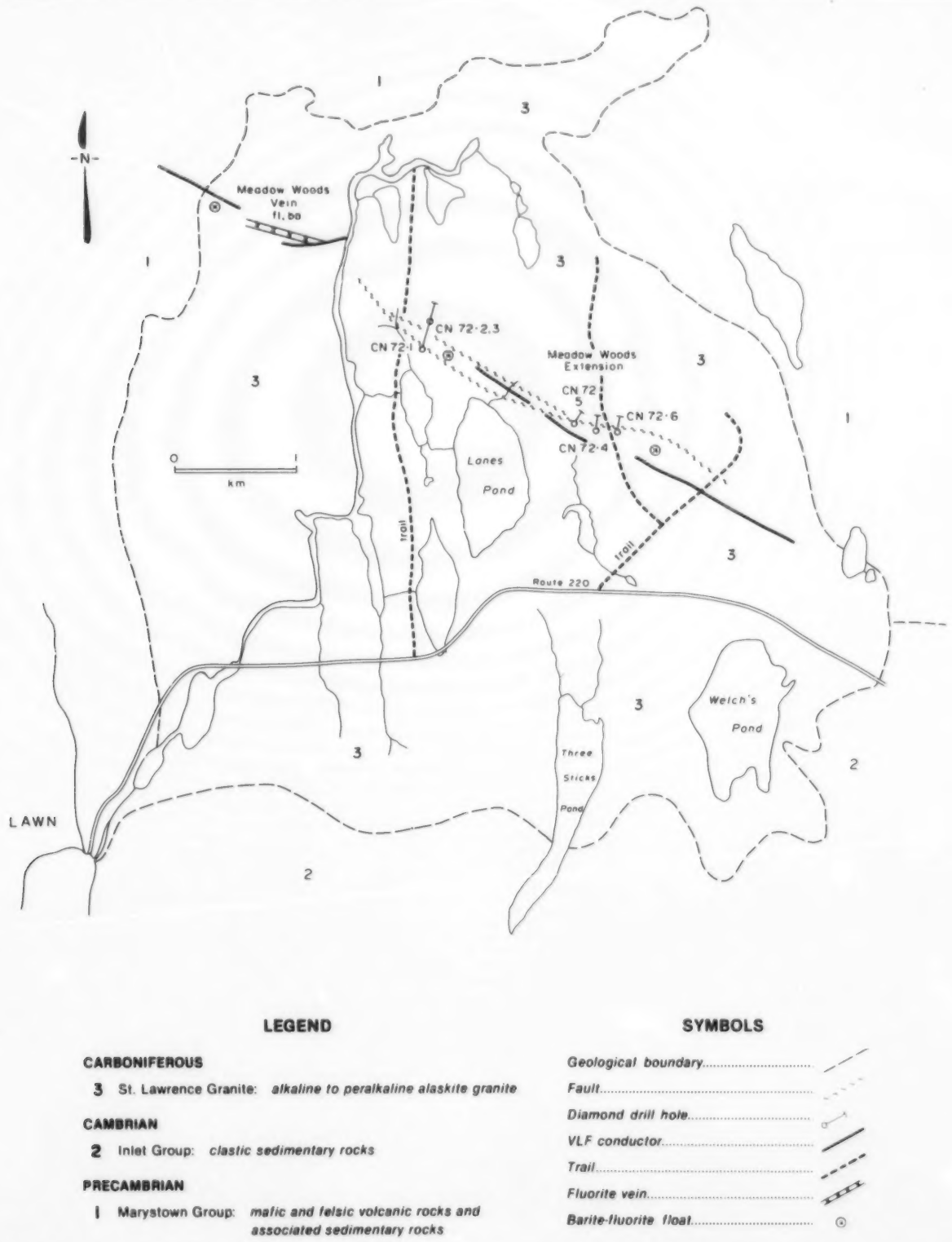


Figure 7. *Location of the Meadow Woods and Meadow Extension veins; also shown are VLF airborne conductors and drillhole locations.*

Table 10. Average analyses of 12 run-of-mine samples from the Meadow Woods Vein exploration shaft, St. Lawrence

	Percent
CaF_2	58.8
$BaSO_4$	15.1
$CaCO_3$	0.6
SiO_2	19.5
Pb	2.2

of the veins barite is the dominant mineral, but in some, fluorite is proportionally greater. The log notes several kaolinized zones, described as faults, in which the rock was very incompetent and core recovery was extremely poor. The log also notes that the mineralized fault zone was intersected at 45°. It is possible that this zone is an eastward extension of the Big Meadow Woods Structure.

Anchor Drogue Vein

The Anchor Drogue vein lies 3.2 km west of Salmonier or about 20 km northeast of the town of St. Lawrence. The vein occurs along a fault that cuts volcanic rocks of the Marystown Group and granodiorite of the Anchor Drogue Pluton. Its attitude is 085/65°N and it has a maximum exposed width of 1.5 m. The vein is composed mainly of green to white coarsely crystalline fluorite, displaying prominent zoning with barite-rich bands on the hanging wall and footwall. Galena occurs as blebs and crystals scattered throughout the vein.

The Anchor Drogue vein was tested by 4 diamond-drill holes in the 1950's (Newfoundland Fluorspar Limited) and 14 holes in the early 1970's (Allied Chemical Corp). The latter program indicated a reserve of about 15 000 tonnes of 40 percent fluorite and about 15 percent barite, in a shallow vein deposit. A chip sample from the barite-rich hanging-wall zone assayed 25.2 percent BaO and 13.0 percent F (Table 11).

Lunch Pond Vein

The Lunch Pond vein is located near the northern tip of Lunch Pond, about 11 km northwest of St. Lawrence (Figure 6). Discovered by Newfluor prospectors in 1950, the vein was trenched and tested by diamond drilling. Although the trenching showed only a 60-cm-wide vein, subsequent drilling indicated extensive mineralization. The best results from the holes drilled showed a cumulative total of 8.4 m of fluorite contained in three sections of 1.2, 4.2 and 3.0 m, respectively. The average grade was 58.8 percent fluorite, including the 3 m section, which averaged 66.5 percent fluorite.

The vein, which is hosted by the St. Lawrence Granite, strikes 065° east and dips 80°N; its strike length is unknown. It contains a mixture of fluorite, barite and calcite along with minor galena. Barite is proportionally less than that contained in the Meadow Woods vein.

Clam Pond Vein

The Clam Pond vein is located on the west side of a stream that flows into the northeast end of Clam Pond. Large angular chunks of red and salmon-pink barite associated with white and blue fluorspar can now be seen in the stream bed, near a small notch that apparently marks the site of the vein. Van Alstine (1948), who investigated the vein reported that much of it consisted of alternating bands (up to 1 cm wide) of red platy barite and white fluorite. Galena and sphalerite were also noted. The vein is hosted by the St. Lawrence Granite.

A grab sample from mineralized float near the vein was collected by the author and the analyses are shown in Table 11.

Main Brook Pond Barite Float

During the stream-sediment survey, numerous trenches containing large blocks of white- and pink-barite float were noted east of Main Brook Pond, about 16 km north of St. Lawrence (Plate 16). These trenches are undoubtedly those described by Smith (1957) as containing extensive barite float. Bedrock is visible in only one trench and consists of mineralized pink, medium to coarse-grained granite associated with finer aplitic zones. Green and white fluorite and pink platy barite, as well as minor galena, occur as float. Dimensions of the mineralized blocks indicate vein widths of 30 cm or more.

Lawn Barite Vein

In 1982, the Lawn barite vein was uncovered during road construction through the community of Lawn. The following description of the vein is a condensed version of an account by Collins (1984). The vein is located on the eastern side of Lawn Harbour and occurs in the Webbers Cove Conglomerate, part of the Upper Proterozoic Marystown Group, a sequence of dominantly subaerial volcanic rocks, which outcrop throughout the Grand Bank and Lamaline region (O'Brien *et al.*, 1977) (Figure 8). The mineralization, exposed in a 25-m-wide roadcut, consists of granite, fluorite, galena and sphalerite in two zones on either side of the road. The main vein is located on the southern side of the road, strikes 105°, dips almost vertically, and can be traced for about 25 m along the outcrop. The vein widens with depth from only 15 cm at sub-outcrop level (1 m below surface) to 60 cm at the road level (about 4 m deeper). Two smaller veins (10 cm wide) were noted near the main vein and may be offshoots from it.

The mineralization in the main vein is primarily pink to white barite having intergrown fluorite and minor zones of galena and sphalerite. Some narrow zones of massive galena and sphalerite are also present. The more massive sections of the vein are characterized by banded white and

Table 11. Assay analyses of some St. Lawrence fluorspar veins that contain barite as gangue

Sample No.	Vein	Remarks	Percent BaO	CaO	SiO_2	F	SrO	Cu	Pb
AH-83-21	Tarefare	chip of small exposed section—see plate	6.94	34.66	19.15	20.57	0.09	-	-
AH-83-26	Church	Representative; brecciated mixture of fluorite and granite with minor blebs of barite	0.16	15.33	62.30	4.58	0.01	-	-
AH-83-41	Clam Pond	Grab; loose fragments containing barite, quartz and fluorite	11.30	15.27	55.30	7.75	0.20	-	0.01
AH-83-39	Meadow Woods	Grab sample of rubble at vein site; vein not exposed	37.70	21.55	11.95	-	0.56	-	0.03
AH-83-42	Meadow Woods	select sample of barite-rich fragment	4.68	33.80	22.80	2.19	0.09	0.01	2.02
	Meadow Woods	Average of 12 run-of-the-mine samples taken during sinking of shaft (Smith, 1957)	9.93	0.34	9.12	28.61	-	-	2.20
AH-83-44	Anchor Droke	chip sample of barite-rich hangingwall zone	25.2	50.40	10.04	13.00	0.53	0.45	0.65
AH-83-31	Lord & Lady	chip sample of vein; minor barite present of open cut on face	0.80	34.10	30.30	19.29	0.03	-	-
AH-83-03	Valley	Representative; barite occurs as gangue in brecciated granite and fluorite	21.70	45.19	4.96	18.33	0.05	-	-

Sampled by A.F. Howse and C.J. Collins (1984)

pink barite, with intimately intergrown fluorite, together with minor bands of massive galena and sphalerite. Breccias are common, and consist of conglomerate fragments within banded crystalline barite and fluorite. Conglomerate with a matrix composed entirely or partially of barite, fluorite and calcite with or without veins or veinlets, is also common.

The conglomerate is relatively unaltered, coarse grained, and has a sandy matrix. Fragments are generally well rounded and include sedimentary and volcanic fragments with fragments of granitic or porphyritic affinity being common.

Other Barite Occurrences

At Ragged Head, about 2 km west of Lawn Harbour, barite is present as large crystals in veinlets up to 30 cm thick along a fault in silicified Cambrian limestone. East of Little St. Lawrence Harbour, in Middle Bight Cove, barite occurs in a shear zone in volcanic rocks of the Burin Group. The zone is about 1.5 m thick and is cut by several barite veinlets ranging in thickness from less than a centimetre to 30 cm. The above occurrences are of no economic value.

Oderin Island Barite Vein

This vein is located on the southwest shore of Oderin Island in Placentia Bay. It appears on Williamson's (1956) map as a 10" (25 cm) wide barite vein. The vein occurs within Upper Proterozoic flat lying mafic flows of the Marystown Group.

FORTUNE BAY BARITE OCCURRENCES

A number of small barite showings have been recorded on and near the northeastern and western shores of Fortune Bay (Figure 1). The showings are too small to command economical interest although they do provide evidence of

Plate 16. *Trenched area, east of Main Brook Pond. Trenches contain granite boulders and barite–fluorite float.*

barite mineralization in the area. There are no chemical analyses available for the occurrences. The following brief account contains all the available information on the showings.

Northeast Fortune Bay

Barite veins are present on the west side of English Harbour East about 150 m from the coast. They occur as fissure fillings in a fault zone (North Shore Fault) in felsic pyroclastic rocks of the Late Precambrian (Hadrynian) Belle Bay Formation. The veins are 5 to 8 cm wide and 1.5 to 3.4 m in length. Calcite and quartz are associated with the barite. Rocks in the vicinity of the veins are stained with malachite and bornite but these minerals are not present in the veins (Bradley, 1955).

Small amounts of barite have also been documented near Cape Mille about 5 km southeast of the English Harbour East occurrences. The barite cements brecciated felsic volcanic rocks of the Precambrian Love Cove Group.

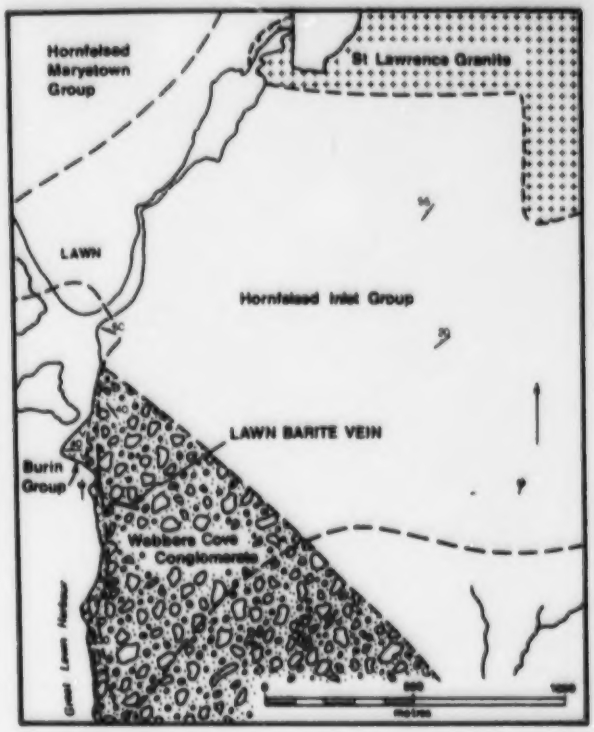


Figure 8. *General geology and location of the Lawn barite vein (after Collins, 1984).*

Western Fortune Bay

Furey (1985) recorded several barite showings on the west side of Fortune Bay in rocks of the Devonian age Belleoram pluton. He noted the presence of barite in a xenolith-bearing quartz–diorite border phase of the pluton about 1.0 km north of the community of Belleoram. Small amounts of barite were also observed in a granodiorite dyke in the pluton about 5.5 km inland from Belleoram, and in quartz monzonite about 2.5 km north of English Harbour West. All of the above occurrences are too small to be of economic interest.

On Belle Isle, a tiny island in northwestern Fortune Bay, Bradley (1955) briefly noted the presence of veinlets composed of quartz, calcite, barite, fluorite, chalcopyrite, and molybdenum, cutting porphyritic alaskite. Also, about 25 km to the east, at Mal Bay, he mentioned occurrences of quartz–galena veinlets containing minor amounts of barite.

PORT AU PORT PENINSULA AND BAY ST. GEORGE SUBBASIN BARITE–CELESTITE OCCURRENCES

INTRODUCTION

Barite occurs with celestite in Carboniferous rocks at a number of locations on the Port au Port Peninsula. The deposits are hosted by limestones of the Codroy Group, which are preserved in a series of north trending, steep-sided, fault-controlled paleokarst valleys that were cut in Ordovician limestones (Figure 9). The mineralization occurs in shaly and sandy limestones and shelly limestones, and is developed as pore and cavity fillings and as replacements of the Codroy limestones. Barite and celestite associated with minor galena and marcasite occur at Boswarlos, Aguathuna Quarry and

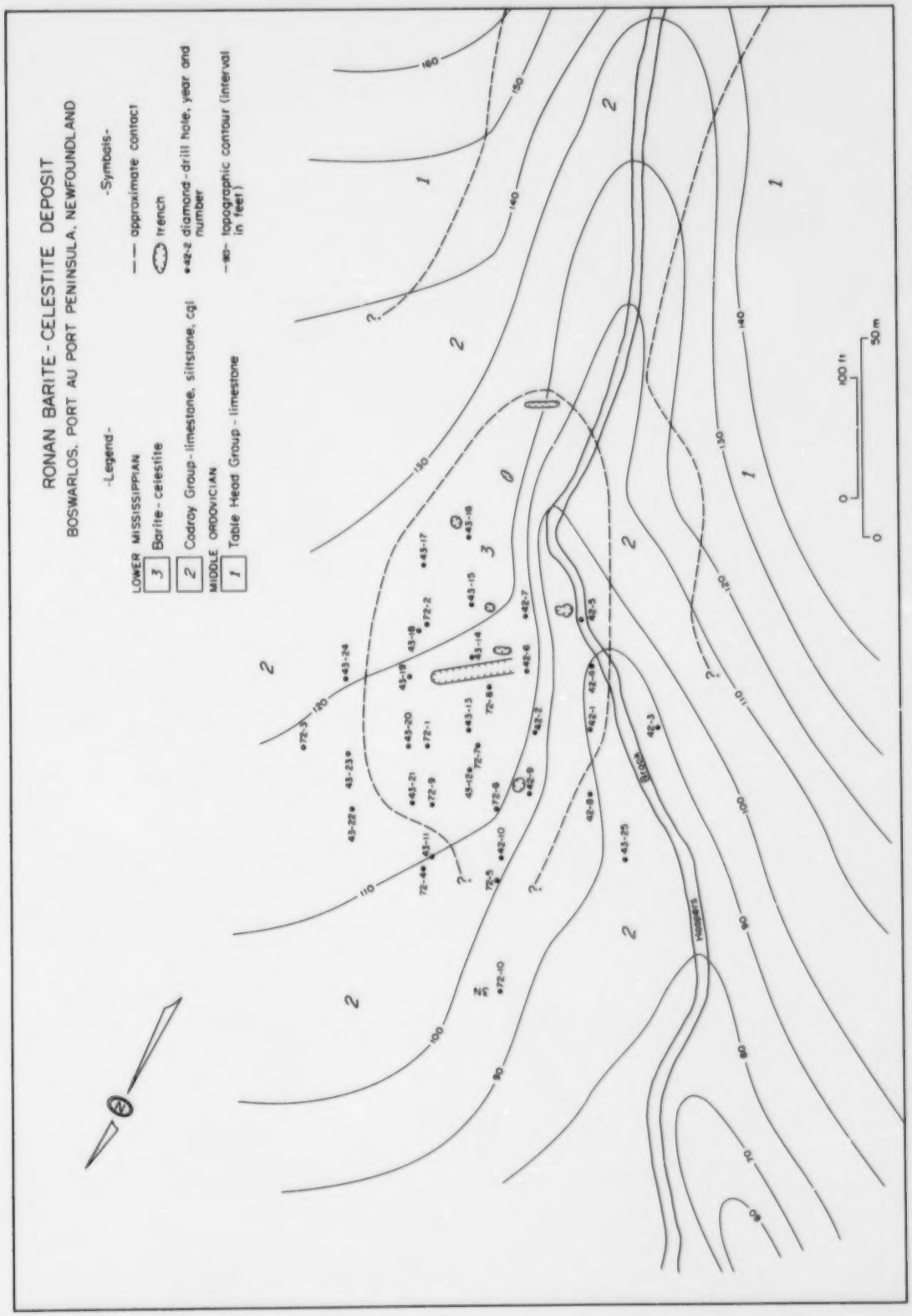


Figure 9. *Plan view of the Ronan barite–celestite deposit, Port au Port Peninsula (modified after Johnson, 1954).*

Gilliams Cove (Johnson, 1954; McArthur, 1973). Small occurrences of barite are associated with the galena–marcasite deposits at Lead Cove, Bellmans Cove and Miners Brook (McArthur, 1973). Extensive barite and celestite float also occurs along a 15-m-section of stream bed, approximately 1 500 m inland from the south shore of Piccadilly Bay (Howse and French, 1983).

Ronan Deposit

Location and Assessment History

The Ronan barite–celestite deposit is located on Hoopers Brook in the community of Boswarlos 800 m southwest of the brook mouth. Originally called the Boswarlos deposit, this name was later officially changed to Ronan deposit in honour of John J. Ronan, who lost his life shortly after making a field assessment of the prospect. The original discovery was made in 1923, when a sample, which was sent to a laboratory in Quebec for analysis, was found to contain 78 percent $SrSO_4$. The property was immediately staked by Arthur House, who later dropped the claim, but reclaimed the ground again when the demand for strontium increased during World War II. The Newfoundland Government carried out an extensive drilling assessment of the deposit in 1942-43 (Johnson, 1954). Ten holes, totalling 150 m, were drilled in 1942 and 15 holes totalling 760 m, in 1943. Plane-table surveying and trench excavation were also done.

In 1972, the Geological Survey Branch of the Newfoundland Department of Mines and Energy further evaluated the deposit by diamond drilling. The main purpose of which was to obtain representative bulk samples for metallurgical tests (McArthur, 1973).

Geology

This deposit is the largest of the known barite–celesite deposits in the Carboniferous rocks of the Codroy Group. It is poorly exposed by trenching; however, it has been fairly well tested by diamond drilling, which shows it to be wedge-shaped in longitudinal section and lens-shaped in cross-section (Figure 10). Limestones of the Table Head Group form a low escarpment to the south of the deposit, and their strata dip 16° to 18° north. A marshy, rolling, drift-covered lowland slopes from this limestone hill to the shore and is underlain by more than 15 m of gently warped basal conglomerates, grey to brown, sandy and shaly limestones, and gypsum-bearing shales of the Codroy Group. These beds rest unconformably on rocks of the Table Head Group and fill irregularities and depressions in the pre-Carboniferous land surface.

The wedge-shaped deposit is conformable with the bedding of the Codroy Group strata and is confined to a pre-Carboniferous depression that may be a buried valley. The thin edge of the wedge is almost exposed in a notch cut by Hoopers Brook through the scarp; the wedge thickens northward to the limit of drilling. It is bounded by the partly exhumed west wall of the subterranean valley and interfingers

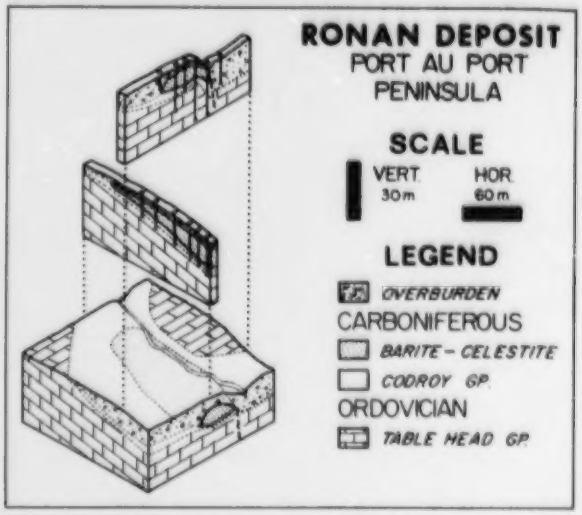


Figure 10. *Block diagram of the Ronan barite–celestite deposit (modified after McArthur, 1973).*

with the unaltered Codroy beds at the limit of drilling to the east.

Johnson (1954) who studied drill cores and samples taken from trenched surface exposures noted the following variations in the modes of occurrence of the different ore minerals: 1) intergrowths of blue granular and radiating white platy crystals of celestite in the groundmass of aragonite and of finely intergrown celestite and aragonite; 2) large lenticles of friable, coarsely crystalline, blue celestite in a buff to brown, shattered muddy limestone; 3) large, rounded crystal masses of celestite, commonly in sharp contact with sugary, white or pink massive barite; 4) an intergrowth of finely crystallized celestite and barite; 5) celestite filling vugs and cavities in limestone; and 6) veins and veinlets of celestite in thinly bedded limestone. A microscopic examination of some ore samples showed that the celestite varied from blue granular masses to white platy crystals, whereas much of the barite proved to be finely crystalline, sugary, massive to open textured. Aragonite and calcite occur as gangue minerals with some gypsum, quartz and kaolin.

Drill-core analyses show that the deposit exhibits zoning with differing strontium/barium ratios at different levels. The ratios can also change horizontally over distance. A narrow, north-trending celestite-rich zone occurs near the centre of the deposit with celestite values varying from 30 to 68 percent over a thickness of 3 to 5.5 m and barite rarely reaching more than 10 percent. The zone is surrounded by barite-rich material grading up to 85 percent barite over thicknesses of 3.5 to 10.5 m. The barite thickens down-dip, whereas the celestite content decreases to less than 5 percent.

Reserves

The wartime drilling program carried out on the Ronan deposit consisted of 10 holes drilled in 1942 and 15 drilled

in 1943. Only assays of the core and sludge from the first 10 are available (Table 12). The results of the other holes are inferred from a series of cross sections presented by Johnson (1954). In the fall of 1972, the Newfoundland Department of Mines and Energy drilled 10 shore holes totalling 160 m in order to obtain representative bulk samples of the deposit for beneficiation tests and to confirm the earlier drilling results.

Table 12. Core and sludge samples from the Ronan barite–celestite deposit, Port au Port Peninsula

Hole No.	Metreage	$CaCO_3$	$SrSO_4$	$BaSO_4$
42-1	4.0– 5.2	10.92	33.20	2.04
	5.2– 6.7	21.50	2.15	29.74
	6.7– 8.2	13.10	1.70	71.89
	8.2– 9.1	19.66	0.14	64.41
42-2	2.7– 4.3	34.37	1.59	43.80
	4.3– 5.8	27.41	0.21	56.71
	5.8– 7.3	8.60	0.31	83.84
42-4	1.2– 2.7	10.17	0.75	81.00
	2.7– 4.3	16.04	6.97	43.85
	4.3– 5.8	22.66	21.75	35.79
	5.8– 7.0	15.10	2.41	73.64
42-5	2.1– 3.7	14.81	1.27	56.61
	3.7– 5.2	14.00	0.70	48.39
	5.2– 6.7	14.21	0.24	68.86
42-6	2.1– 3.7	12.54	60.33	6.94
	3.7– 5.2	11.10	67.48	7.57
	5.2– 6.1	14.17	54.11	6.11
	6.1– 7.0	6.35	61.06	9.31
42-7	3.4– 4.6	25.74	55.81	2.77
	4.6– 6.1	14.81	43.61	7.82
42-9	6.1– 7.6	10.38	61.59	4.41
	7.6– 9.1	39.55	30.51	21.11
42-10	2.1– 3.7	45.12	4.34	48.43
	3.7– 5.2	51.90	2.55	30.87
	5.2– 6.7	38.37	2.93	35.74
	6.7– 8.2	14.45	2.05	87.66
	8.2– 9.8	16.52	1.59	71.08
	9.8–11.3	15.56	0.21	68.21
	11.3–12.8	13.42	0.28	77.44

The south and west limits of the deposit have been delineated by holes 42-3, 42-8 and 43-25. Holes 43-22, 43-23, 43-24 and 72-3 indicate the eastern boundary (Figure 10). The 1972 drilling did not conclusively determine the northern down-dip limits of the deposit. Hole 72-5 showed a 9 m section, and averaged 56.4 percent barite and 5.26 percent celestite. Hole 72-10, which is the most northerly, did not penetrate bedrock although the relatively thick overburden (more than 10 m) may suggest that the host Codroy sediments and mineralization may be thin or nonexistent at that location.

The wartime and 1972 drilling has outlined a shallow deposit with an areal dimension of 75 x 100 m and a thickness ranging up to 12 m. It contains at least 130 000 tonnes of mixed barite celestite, with grades in the range of 35 percent barite and 25 percent celestite.

Metallurgical Tests

In 1972, the Geological Survey Branch of the Newfoundland Department of Mines and Energy drilled 10 short holes in order to obtain a representative bulk sample of the Ronan deposit for metallurgical tests at the Atlantic Industrial Research Institute (A.I.R.I.), in Halifax. Electron microprobe analysis indicated that there is solid solution of celestite in barite and vice versa (Grice, 1974). From some of the assays of the drill core the extent of the solid solution appears to be around 1 to 5 percent.

A flotation test using a celestite-rich zone grading approximately 63 percent celestite produced an 84 percent concentrate, using reagent Dripon 181. A heavy-liquid separation test using a representative composite sample of the whole deposit showed that the gangue could easily be removed from the sulphates. However, an attempt to separate barite from celestite resulted in a high-grade barite concentrate and a low-grade mixed celestite–barite concentrate. The separation process involved a heavy media of finely divided lead particles, which were very costly compared to the market value of the concentrates at the time the tests were carried out.

Gillams Cove Prospect

The Gillams Cove Prospect lies about 0.8 km west of Aguathuna in the northern end of a small valley, within 100 m of the Boswarlos road. The geology and mineralization was described by Johnson (1954).

Barite and celestite mineralization is exposed in trenches in the stream bank. Excellent samples may be collected from the float in and near the northern end of the small valley. On the east wall of this valley, a bench of horizontal Codroy Group strata is bounded on the west by the brook and on the east by a wall of Table Head limestone at the west end of the Aguathuna Quarry. The Codroy beds are buff to brown, sandy to shaly limestone that enclose irregular masses of sulphate minerals at the base of the cliff. The visibly mineralized zone is approximately 3 m thick and may extend below sea level. It is exposed for a short distance inland along the side of the valley. Minor patches of similar mineralization occur 300 m west of Gillams Cove, outcropping in a coastal exposure and south of the road.

The mineralized zone is a mixture of crushed and shattered sandy limestone in irregular bouldery masses, together with crystalline aggregates of celestite that enclose

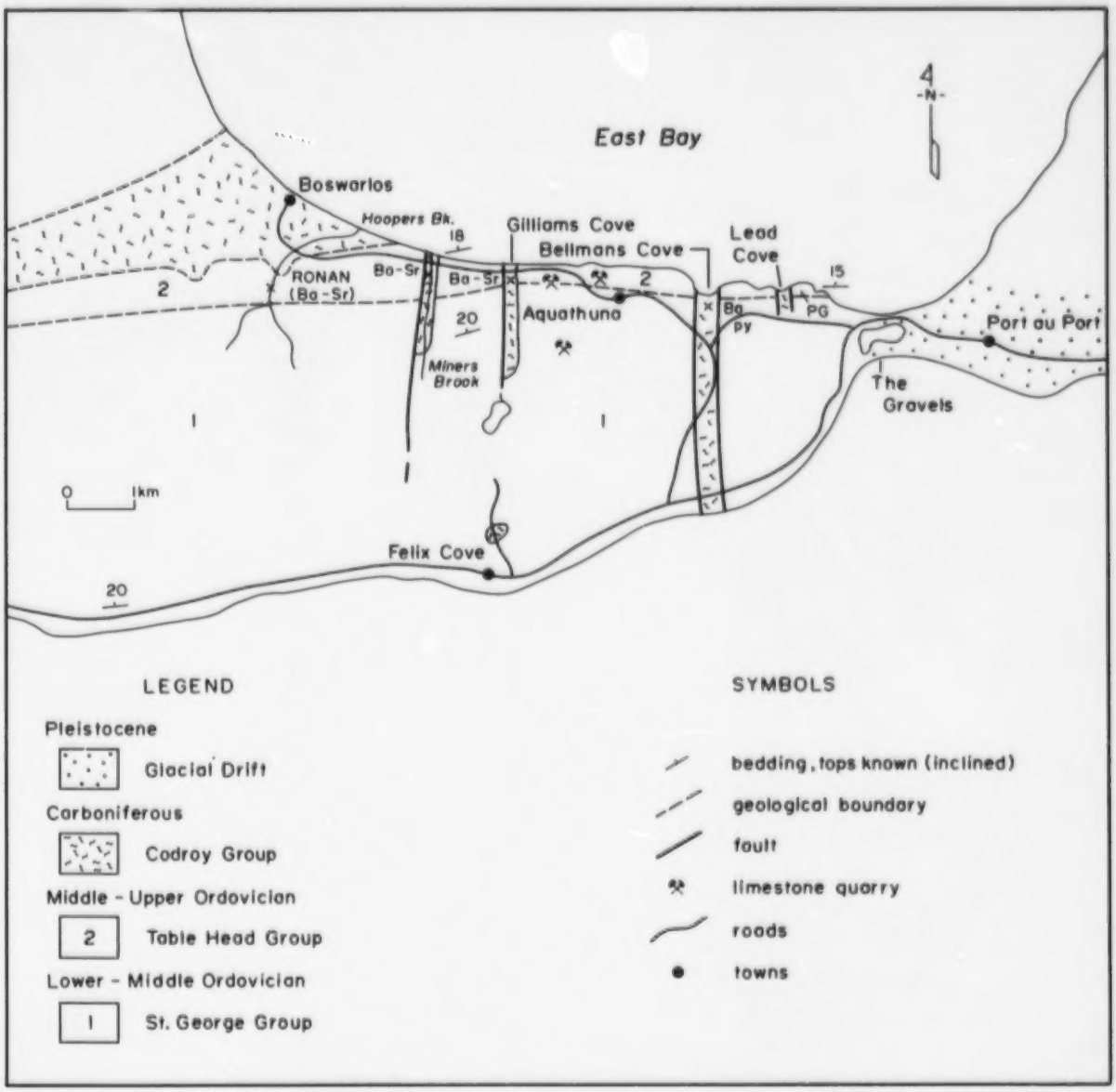


Figure 11. *Barite–celestite occurrences on the Port au Port Peninsula.*

smaller amounts of barite, calcite and aragonite. The small deposit measures about 45 x 75 x 2 m in size and probably contains about 16 000 tonnes of mixed celestite and barite.

Other Occurrences

Minor amounts of barite with celestite occur in the Aguathuna limestone quarry and in mineralized zones in nearby Bellmans Cove and Miners Brook (Figure 11).

The Aguathuna Quarry occurrence consists of celestite and barite as open-space fillings in a small outcrop of shelly Mississippian limestone preserved on the quarry floor.

In Bellmans Cove, minor amounts of barite occur along with marcasite, sphalerite and calcite in brecciated Mississippian limestone.

The Miners Brook showing is about 1 km west of the Gillams Cove deposit. It is characterized by galena, marcasite and minor sphalerite disseminated in a vuggy fossiliferous limestone, which outcrops in the stream. Barite is found as small crystals in vugs, or as thin blades associated with galena and marcasite.

Three other relatively minor barite occurrences have been recorded in the Port au Port area. One is located at Fiods

Cove on the south shore of the peninsula, another occurs in the peninsula's interior, about 6 km east of the community of Mainland; a third is located on the southeast side of Romaines Brook about 7 km east of the Gravels.

At Fiods Cove, thin platy crystals of barite are associated with northeast trending, steeply dipping calcite veins. The margin of the veins consist of finely-banded, brown, grey, and white fibrous calcite. Barite is associated with the calcite in vugs. Galena and marcasite are present in small amounts. The veins occur in flatly dipping limestone beds of the Lower Ordovician, St. George Group.

The Upper Mainland Brook occurrence is located near the crest of a densely wooded ridge about 6 km of the community of Mainland. Three shallow trenches, spaced about 18 m apart, have exposed a southwest striking zone of calcite and limestone. Vuggy, iron-stained sections in the middle trench contain coarse crystals of barite and galena. The zone, which is approximately 4 m wide at its southwesterly half, narrows to the northeast (Gilchrist, 1928). The mineralization occurs in limestones of the St. George Group.

The barite occurrence on Romaines Brook consists of several vuggy veins of quartz and barite cutting quartzite. Several well-formed colourless and transparent barite crystals 2 to 5 cm in diameter were noted (Walthier, 1949). The host rocks are Lower Cambrian sedimentary rocks of the Kippens Formation.

SUMMARY AND DISCUSSION

Small deposits of mixed barite and celestite occur as replacement deposits in Upper Mississippian limestone beds on the Port au Port Peninsula. The occurrences are associated with fault-bounded paleokarst valleys that have been cut in Ordovician limestones. With the exception of the Ronan and Bellmans Cove deposits most appear to be erosional remnants of larger bodies and are of no economic interest.

The Ronan deposit has been fairly well delineated by drilling although the northward, down-dip part of the sulphate body has not been clearly defined and can still be considered open. Metallurgical tests have demonstrated that separation of sulphates from gangue can be accomplished, but complete separation is difficult because a small proportion of the barite and celestite is in solid solution.

The drift covered terrane between Boswarlos and Piccadilly Bay may contain other such deposits, and this presents a challenge for geophysical prospecting methods. The problem poses interesting possibilities for the application of gravity, seismic and possibly VLF-EM techniques. A trial gravity line run over the Ronan deposit indicated a weak positive gravity anomaly (Hodych, 1974), and a VLF-EM survey conducted by this author, over the same deposits, showed that the Carboniferous–pre-Carboniferous contact with which the occurrences are associated, can be accurately traced by such a technique, at least in areas of thin overburden. Subsequent work by Todd (1986) showed that the VLF technique could effectively locate the contact in the area west of Boswarlos and thus identify the ground with highest potential for barite–celestite deposits.

BAY ST. GEORGE SUBBASIN AND GREAT NORTHERN PENINSULA BARITE OCCURRENCES

INTRODUCTION

Barite associated with small veins of calcite and associated base metals have been documented in a number of localities in the Bay St. George subbasin (Knight, 1983). In 1982, while investigating barium anomalies that were identified in stream and lake sediments (McArthur *et al.*, 1975), a number of new showings of metallic and non-metallic minerals were discovered (Howse and French, 1983). Most of the occurrences are located in areas underlain by shales and sandstones of the Lower Mississippian Anguille Group, whereas others are hosted by basal limestones overlying the Mississippian Codroy Group (Figure 12).

Nearly all of the barite that was identified in Carboniferous strata occurs as narrow veins ranging in thickness up to 20 cm. Barite containing quartz and calcite were observed in brecciated zones in Anguille Group sandstones. Narrow veins of mixed barite and calcite were also noted in Ship Cove limestone of the Codroy Group. In one showing, on a small stream flowing into Brooms Brook, barite mixed with calcite occurs as gangue in narrow mineralized fractures containing sphalerite, chalcopyrite, and galena in Ship Cove limestone. On Bald Mountain, an area, which showed anomalous amounts of barium in both stream and lake sediments, narrow veinlets of barite cut red and grey sandstones of the Anguille Group.

A comprehensive memoir by Knight (1983), which presented the results of several years of regional (1:50 000) mapping and detailed stratigraphic studies, has provided stratigraphic settings for mineral occurrences in the Bay St. George subbasin. The following account of the geology is based on his work.

Geology

The strata were divided into three groups, the Anguille, Codroy and Barachois groups (Bell, 1948; Baird and Côté, 1964). Most of the rocks represent nonmarine, terrigenous, clastic sediments although marine strata are locally present within the Codroy Group.

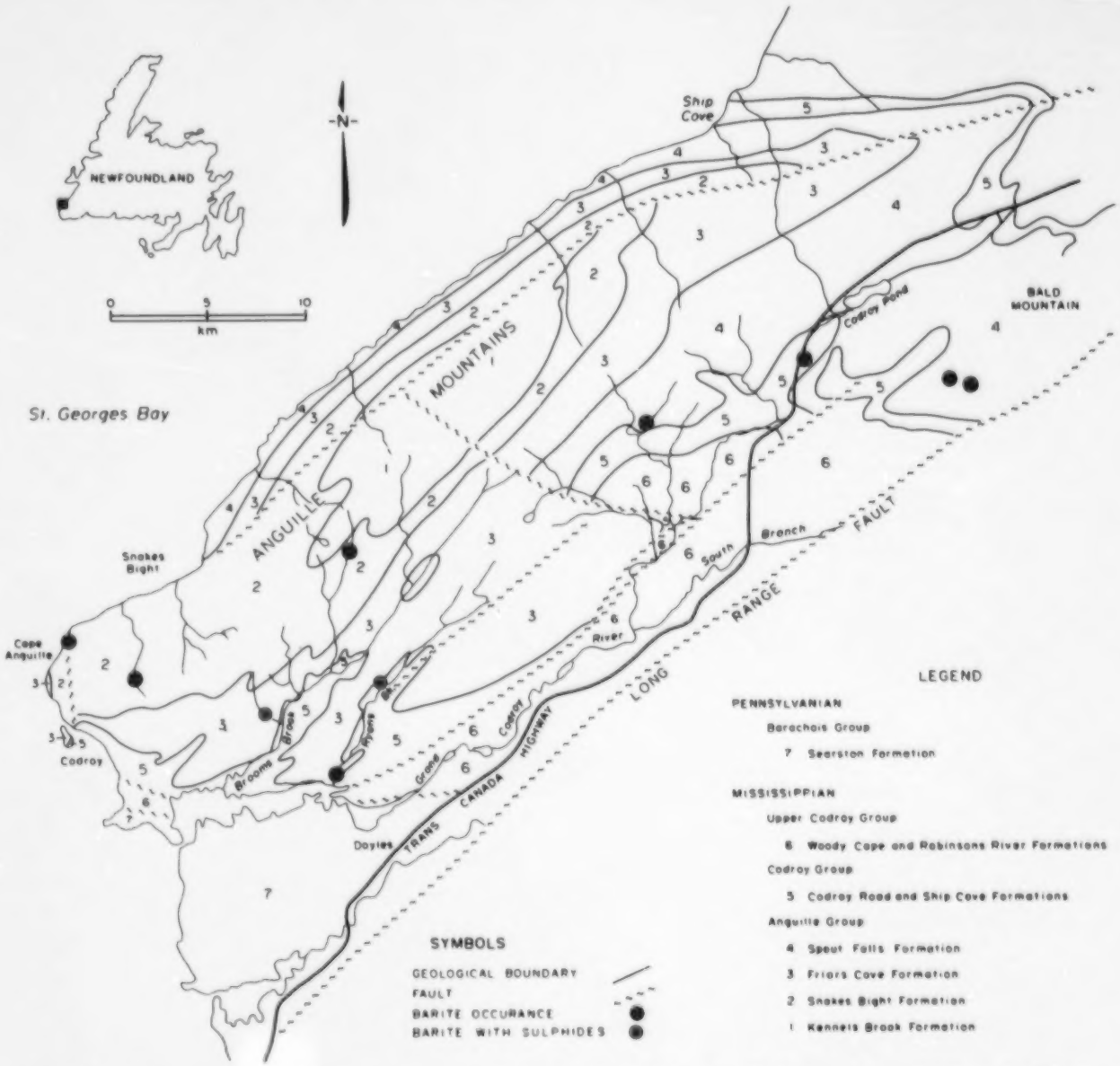


Figure 12. *Sketch map showing location of barite occurrences in the Codroy–Anguille Mountains area (geology after Knight, 1985).*

The Anguille Group, the oldest strata in the subbasin, underlies the Anguille mountains and the area around Bald Mountain. Knight (1983) subdivided the Anguille Group into four formations which he termed: (1) the Kennels Brook formation, consisting of red and green sandstone associated with intercalated grey sandstone and red siltstone interpreted to be deposited by braided and meandering streams; (2) the Snakes Bight formation consisting mainly of black shale and mudstone interpreted to reflect a lacustrine, deep water depositional environment; (3) the Friars Cove formation consisting of grey fluvial and deltaic sandstone and shale overlying a thin basal conglomerate and (4) the Spout Falls formation consisting of red braided stream sediments. .

The Codroy Group, which appears to conformably overlie the Anguille Group, consist of a complex succession of limestones, redbeds, shales, siltstones and conglomerate. Knight (1983) subdivided the group into several formations and members, which reflect a wide variety of marine and nonmarine depositional environments.

The lower units of the Codroy Group include the basal Ship Cove Formation consisting of laminated limestones, the

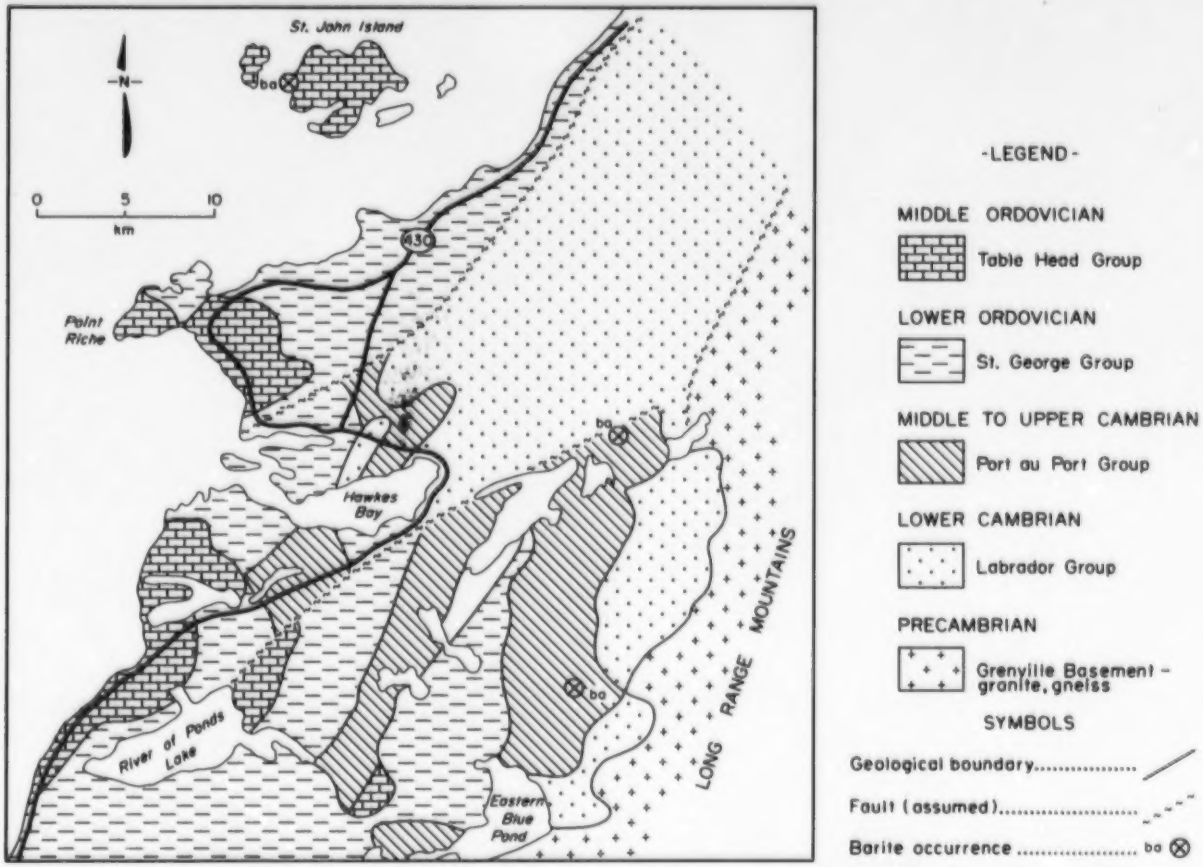


Figure 13. *Barite occurrences near Hawkes Bay, Great Northern Peninsula (after Knight and Boyce, 1984).*

Codroy Road Formation consisting of siltstones, mudstones, sandstones and thick gypsum and anhydride, and the lower Jeffrey's Village member of the Robinsons River Formation consisting of red siltstone, red and grey sandstones, mudstones, caliche limestone gypsum, anhydrate and salt.

The Barachois Group of Late Mississippian to Pennsylvanian age is believed to conformably overlie the Codroy Group, although this is uncertain because contacts between the two groups are faulted. The Barachois Group consist of undivided fluvial siltstones and sandstones. Thin coal seams also occur in the group.

Barite and Associated Minerals

Barite, calcite and associated metals (chalcopyrite, pyrite, galena, sphalerite) occur as (1) stratabound vein mineralization within clastic rocks of the Snakes Bight Formation of the Anguille Group and (2) vein type mineralization associated with the Anguille–Codroy Group contact (Knight, 1983). Stratiform mineralization consisting of disseminated galena, sphalerite, chalcopyrite and pyrite in thin laminations is also present in places, but no barite has been identified with this type of occurrence.

(1) Minor amounts of barite occur in small faults, joints and fractures that cut the black shale of the Snakes Bight Formation. The mineralization is similar, although not as widespread as the showing of chalcopyrite, sphalerite, galena and pyrite that also occur, mainly associated with calcite veinlets. Disseminated galena, sphalerite, chalcopyrite and pyrite have also been noted in sedimentary laminations within the black shales (Howse and French, 1982).

Barite was also noted in red sandstone, during an investigation of a barium geochemical anomaly on Bald Mountain (Howse and French, 1982) that was detected in an earlier regional stream-sediment survey (McArthur *et al.*, 1975). The barite, along with calcite, occurs as thin films along joints and fractures. The host rocks are part of the Spout Falls Formation of the Anguille Group.

(2) The Anguille Group–Codroy Group contact is stratigraphically important because of the metallic and non-metallic mineralization associated with it. Mineralization occurs in the Ship Cove limestone and underlying sandstone of the Anguille Group. The minerals including barite, chalcopyrite, chalcocite, galena, sphalerite and pyrite associated with hematite, malachite and fluorite, occur as small clots and disseminations with calcite in fractures and as joints. Barite, the chief vein mineral, occurs in several localities along Ryans Brook and a tributary of Brooms Brook (Figure 13). The following are descriptions of these showings.

Table 13. Assay analyses of barite–calcite veins in the Ryans brook–Brooms brook area, Anguille Mountains

Sample and Ref. No.	Location and Description	BaO	SrO	SO_3	SiO_2	CaO	L.O.I.
5142023 1	Ryans Brook–mixed barite and calcite vein	43.36	5.54	29.94	1.30	12.53	9.97
5142024 1	Ryans Brook–mixed barite and calcite vein	53.31	7.28	32.55	0.43	3.64	3.02
5142028 2	Brooms Brook–calcite and minor barite	0.12	0.95	0.09	2.19	54.13	42.61
5142027 3	Ryans Brook–calcite and minor barite, also minor sulphides	3.51	0.43	2.15	4.32	48.95	38.65
5142025 4	Brooms Brook Tributary–barite in fault zone	54.69	6.24	33.46	2.68	0.66	0.78
5142029 5	Ryans Brook–mixed barite and calcite vein	42.11	3.51	23.70	4.79	13.31	10.88
5142026 6	Bald Mountain–mixed barite and calcite	47.31	6.70	28.66	8.90	3.08	3.01

Barite in the Ryans Brook–Brooms Brook Area

Ryans Brook (South) Showing

Knight (1983) described a cluster of veins, which are exposed along Ryans Brook, about 500 m upstream from the highway bridge. Most of them are a few centimetres to 40 cm wide cutting limestones of the Ship Cove Formation close to an important fault, that downthrows the limestones against green-grey sandstones of the Anguille Group. The fault strikes 300° and dips 45° to the north. Close to the fault surface, barite veins strike 110° and dip 85° south. The veins occur in a zone, several metres wide, composed mostly of limestone cut by numerous 1- to 7-cm-wide veins of calcite and barite. Within this zone, is a vein approximately 3.5 m thick composed of massive, crystalline, pinkish-white barite and grey and white, foliated barite and calcite. Table 13 shows the results of the assay analyses of the barite–celestite veins. Alignment of limestone fragments occurs in the foliated margin of the vein. Other mineralized tension fractures and veins up to 20 cm wide occur upstream within 30 m of the fault. They include barite and calcite with disseminated chalcopyrite and malachite.

Quarry Showing

This barite showing is located in an abandoned limestone quarry on the highway immediately west of the bridge over Ryans Brook. A family residence on a landscaped lot now occupies the site of the former quarry. Barite occurs as joint coatings, disseminations and clots within limestones of the Ship Cove Formation and underlying sandstones of the Anguille Group. At the base of the limestone, the vein and joint fillings range from 2 to 5 cm in thickness. The limestones are locally brecciated. Veins trend 180°/75° W and 110°/77° S (Knight, 1983).

Ryans Brook (North) Showing

The Ryans Brook (North) showing was discovered during the course of an investigation of stream-sediment barium anomalies (Howse and French, 1983). It is located about 4 km upstream from the Ryans Brook bridge and can be easily reached via a 3-km long logging road that branches off the O'Regans highway, about 10 km east of the bridge. The minerals are exposed in bedrock on the northwest bank of the stream.

The minerals, consisting of sphalerite, galena, chalcopyrite, pyrite, calcite and barite, occupy tension fractures along the axis of a tight fold in limestone. Sphalerite, the dominant base metal, appears as prominent crystals on the weathered surface. Blebs and clots of galena (1 to 2 cm in diameter) similarly occur. Pyrite occurs and can be seen as thin (1 to 2 mm) bands in the limestone. The minerals are mainly associated with anastomosing calcite and barite stringers in the fractures. The mineralized zone which trends 160° and dips 66 northeast, is about 50 cm wide and is traceable for 8 m.

A steeply dipping 30-cm-wide vein of mixed calcite and barite occurs near the footwall of the zone. It has the characteristic steel grey colour of similar mixed calcite–barite veins in the area. The vein is exposed in the face of an outcrop, which forms the west bank of the stream; its inland extension is obscured by overburden and brush.

Brooms Brook Vein

This occurrence is located on a stream, which flows southeastward into Brooms Brook, a major tributary of the Grand Codroy River. Barite associated with calcite occupies a fault zone exposed on the north bank of the stream. The barite and calcite comprise a steeply dipping vein that strikes 040° and dips 75° to the northwest. The vein has a maximum width of 20 cm at the top of a 5 m cliff but is reduced to stringers at stream-bed level. Angular fragments of green sandstone are included in the vein. Small bladed crystals of pink and white barite are also present. The vein contains calcite- and barite-rich zones with each mineral present in approximately equal amounts. The vein is located near the contact between Friars Cove Formation sandstone of the Anguille Group and the overlying Ship Cove Formation limestone of the Codroy Group. Table 13 illustrates the assay analyses of barite veinlets in the vein.

Bald Mountain Barite Occurrences

The regional stream-sediment survey carried out by McArthur *et al.* (1975) showed that the areas underlain by

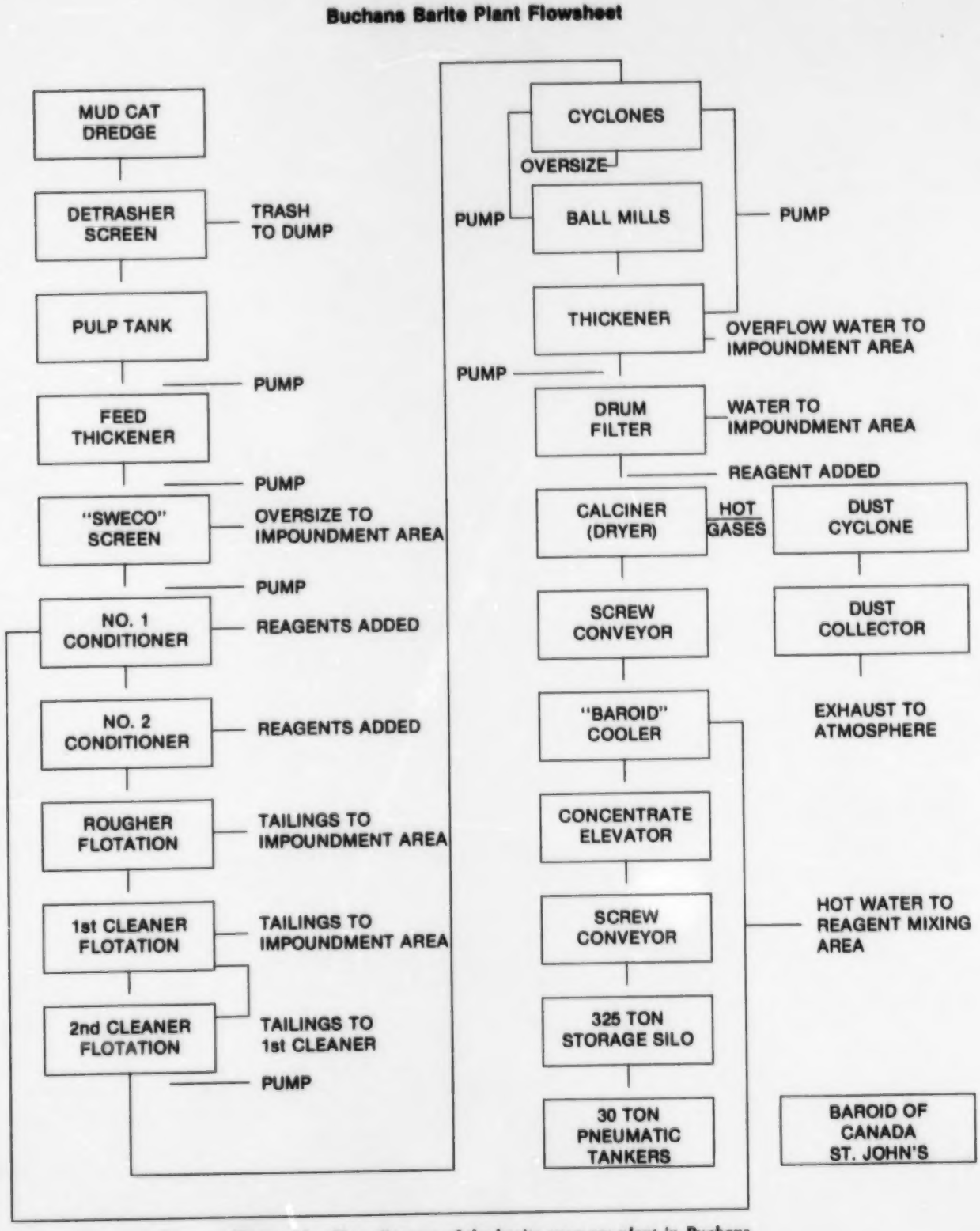


Figure 14. *Flow diagram of the barite recovery plant in Buchans.*

the Spout Falls Formation immediately below the Ship Cove Formation are anomalous in barium and lead in the Bald Mountain area. Ground follow-up of an anomalous stream, which drains the south flank of Bald Mountain, discovered minor but pervasive barite mineralization in several outcrops along the stream bed (Howse and French, 1982).

The barite is associated with white- and red-stained calcite as joint and fracture fillings in red sandstone, which contains silty shale interbeds. The gently dipping beds (115 to 120°/15° SW) are cut by a prominent east-west vertically dipping joint set, which contains films of barite up to 1 cm thick. White- and pink-bladed crystals of barite occur on the joint planes and in one exposure is traceable for 4 m across the brook. The host sandstone is ripple marked and locally distorted by small slump folds.

Trans-Canada Highway Occurrences

This showing is located in a rock cut on the Trans-Canada Highway, 2 km north of the bridge, which spans the north branch of the Grand Codroy River. Barite and calcite are present as joint coatings, disseminations and clots in dark green, massive but highly fractured sandstone. Smears of malachite, separated from the barite and calcite are also present. The mineralized zone includes brecciated areas consisting of angular sandstone fragments cemented by white and pink partially crystalline barite. The zone, which appears to be at least 2 m wide, can be traced for about 20 m along its strike (180°). Prominent slickensides, subparallel to bedding planes, are prominent in the host sandstone.

Snakes Bight

During follow-up of stream-sediment barium anomalies in 1982 (Howse and French, 1983), minor amounts of barite were noted in several outcrops along streams that cross clastic sedimentary rocks of the Snakes Bight Formation. Thin coatings of barite and calcite are present on fractured, gently dipping slaty mudstone in an unnamed stream whose headwaters are located in a bog immediately north of the steel communications tower atop the Anguille Mountains. About 1.5 km southeast from the eastern end of the Union Oil road, mixed bluish-grey veinlets of barite and calcite occur in thin (8 cm wide) lenses of shale in limestone which strikes 030° and dips 55° southeast. The barite bearing shale can be traced for 10 m along the strike of the limestone bed.

Barite Occurrences Near Hawkes Bay, Great Northern Peninsula

The only documented barite occurrences on the Great Northern Peninsula are those reported by Knight and Boyce (1984), which were discovered during their regional mapping program in the Hawkes Bay area and on St. John Island.

In one occurrence, located along a forest access road about 12 km southeast of Hawkes Bay, pink barite crystals are present in small vugs and open spaces in dolostones. The syngenetic dolostones are interbedded in a shale sequence, which forms part of the Late Cambrian Petit Jardin Formation of the Port au Port Group (Figure 14).

A similar occurrence is located about 10 km due north of the one described above. Long, thin, platy white crystals of barite are intimately associated with rhomboid and saddle back crystals of dolomite within vugs that are several centimetres in diameter. In some vugs, interlocking crystal aggregates of white to translucent grey barite fills much of the voids. The host dolostones are part Petit Jardin Formation.

On St. John Island, minor amounts of sphalerite, galena, quartz and barite are associated with small calcite veins, which cut rocks of the Middle Ordovician Table Head Formation.

CONCLUSION

Numerous occurrences of barite have been documented in the Bay St. George subbasin. The barite occurs as a gangue in veins, which together with calcite, commonly host minor amounts of base metals. None of the veins that have been identified are large or pure enough to be of economic interest.

Documented occurrences of barite on the Great Northern Peninsula are too small to be of economic interest.

CENTRAL NEWFOUNDLAND BARITE OCCURRENCES

BUCHANS TAILINGS DEPOSIT

Introduction

The largest reserve of barite in Newfoundland is contained in two tailings ponds or reservoirs at Buchans in central Newfoundland. The mill tailings, which average about 35 percent barite, accumulated from the mining and milling of a number of baritic polymetallic massive-sulphide deposits that are located about 6 km north of Red Indian Lake. The deposits (now exhausted) are hosted by the Buchans Group, a complex assemblage of mafic to felsic volcanic rocks of presumed Early Ordovician age (Nowlan and Thurlow, 1984; Dunning *et al.*, 1987).

A Micmac Indian, Matty Mitchell, made the first discovery of ore in the area in 1905, when he located the Buchans River ore body. This deposit was developed by shafts and drifts, and about 100 000 tonnes of extremely fine-grained baritic zinc–lead–copper sulphide ore was indicated. Metallurgical difficulties prevented further development until 1925, when the American Mining and Smelting Co. succeeded

in developing a satisfactory economic separation of the sulphides by a method of selective flotation. Intensive exploration, which was begun in the following year resulted in the discovery of additional major ore bodies including the 'Lucky Strike' orebody located about 1 km west of the Buchans River deposit and the 'Oriental' orebody 600 m east of the original discovery. Later major finds included the Rothermere and MacLean ore bodies.

Barite was the most abundant gangue mineral in the Buchans ore, which comprised a fine grained mixture of sphalerite, galena, chalcopyrite with lesser amounts of pyrite and minor tetrahedrite. Also quartz, calcite, sericite and chlorite were minor gangue constituents. Three main types of ore were recognized in the Buchans deposits: (l) stockwork ore, consisting of networks of veinlets and disseminated base-metal sulphides within silicified and locally chloritized host rock (2) *in situ* ore, composed of banded to streaky yellow ore, black ore and barite, and, (3) transported ore, which consisted of sulphide and barite fragments that were derived from (2) (Thurlow and Swanson, 1981).

During the life of the Buchans mining operation approximately 16 million tonnes of ore were produced from four shafts. Milling of the ore was complicated by the fine grained nature of the ore aggregate. Grinding was carried out to 73 percent in a 325 mesh, for example, but extremely fine grained ore required grinding to 20 microns for complete separation. Different orebodies and different sections of the same orebody had their own flotation characteristics (Swanson *et al.*, 1981).

Mill tailings, prior to 1966, were carried by flume and drainage ditch into Buchans River, which flows into Red Indian Lake about 5 km south of the mine. Because of the size of the lake (180 km^2), it is likely that these tailings have been thinly dispersed over a large part of the lake bottom; thus they are considered unrecoverable.

Beginning in January 1966, all tailings were directed into settling ponds near the plant. The potential value of the barite content was long recognized, but early interest was primarily concerned with its possible application in the manufacture of paints and glass. Offshore oil and gas exploration focussed attention on its potential use as a weighting agent in drilling fluids. Beneficiation studies carried out by CANMET on a bulk sample of the Buchans base-metal tailings showed that a barite concentrate could be produced suitable for use as an additive in drilling mud (Hartman and Wyman, 1974). The potential offshore market led to the design of a plant capable of recovering barite from the tailings and an agreement to construct such a plant was signed in the fall of 1980 by Abitibi-Price, ASARCO and NL BAROID. The Department of Regional and Economic Expansion (DREE) provided a $400 000 development incentive grant. The plant was officially opened in August, 1981 and operated intermittently until the closure of the Buchan Mine in 1984. The Buchans Development Corporation, for a nominal fee, acquired the barite plant in 1986 along with the other assets of the former lead–zinc mining operation.

Barite Recovery Plant

The barite recovery plant is located about 600 m from the tailings pond. When in operation, the following process took place. At the pond a small dredge (Mud Cat) with a hydraulically operated auger-cutter scooped out the tailings from the pond (Plate 17). The auger-cutter was lowered into the tailings material where it cut a path 2.7 m wide and 45 cm deep. The cutter loosened and directed the material into a suction pump where it was pumped through a pipeline to the plant at the rate of 1 600 litres per minute. The pulp passed through a single deck vibrating screen where any wood chips or oversize pieces of material were removed. This waste (trash) went into a hopper for removal to a dump while the remaining pulp entered a milling process involving thickening, screening, chemical treatment, flotation and dewatering.

Plate 17. *Buchans tailings pond showing 'mud cat'.*

The dewatering phase used a calciner (dryer) 1.8 m in diameter and 10.5 m long with a four million BTU per hour furnace attached at the discharge end. Hot (650°C) gasses are pulled through the calciner by a exhaust fan. The extreme temperatures are required for burning off residual chemicals, which were used in the flotation process.

The 85 to 90 percent barite concentrate was automatically conveyed to the storage silo which consists of a large steel tank capable of holding up to 325 tonnes. The concentrate was transferred from the silo via a screw conveyer and a bucket elevator and loaded into 30 tonne pneumatic tanker trailers for transportation to the Baroid of Canada Service Centre near St. John's.

Reserves–Production

The barite plant, operating seasonally, is capable of producing 15 500 tonnes of barite concentrate annually.

Sufficient reserves are available to sustain such a rate of production for many years. Although mill tailings prior to 1965 are considered lost, there are about 1.5 million tonnes of recoverable material available in the two controlled ponds. Barite comprises about 35 percent of the tailings (Table 14). Other waste materials present include silica, ground volcanic rocks, and minor amounts of zinc, lead and copper, which escaped the normal recovery system in the original milling process.

Table 14. Assay and screen analysis of a sample of the Buchans tailings composite (1970)

Percent

$BaSO_4$	SiO_2	Al_2O_3	CaO	Fe	Cu	Pb	Zn
32.4	36.6	4.0	5.4	4.3	0.11	0.42	1.14

+ 200 mesh 28.8	- 200 mesh 71.8
+ 325 mesh 15.4	- 325 mesh 56.4

Source ASARCO (1970)

Production to date has been erratic and minimal. The plant operated for two months in 1982 and produced 3 817 tonnes of barite. It was idle in 1983, and in 1984 produced 5 000 tonnes. The lack of consistent production has been caused by a combination of problems related to markets, high cost of transportation, and competition from other barite producers.

GLITTER POND PROSPECT

The Glitter Pond Barite Prospect is located about 10 km southeast of Red Indian Lake and is accessible to within a few hundred metres by Abitibi-Price woods roads (Figure 15). The showing consists of an intimate mixture of white and grayish white barite and quartz that is exposed, partly by trenching on the crest of a 240° trending ridge. Barite, which appears to be the dominant mineral, includes some large white translucent crystals in bladed form. Minor amounts of pyrite are present as small clots and bands. The mineralization is traceable along the ridge for approximately 20 m.

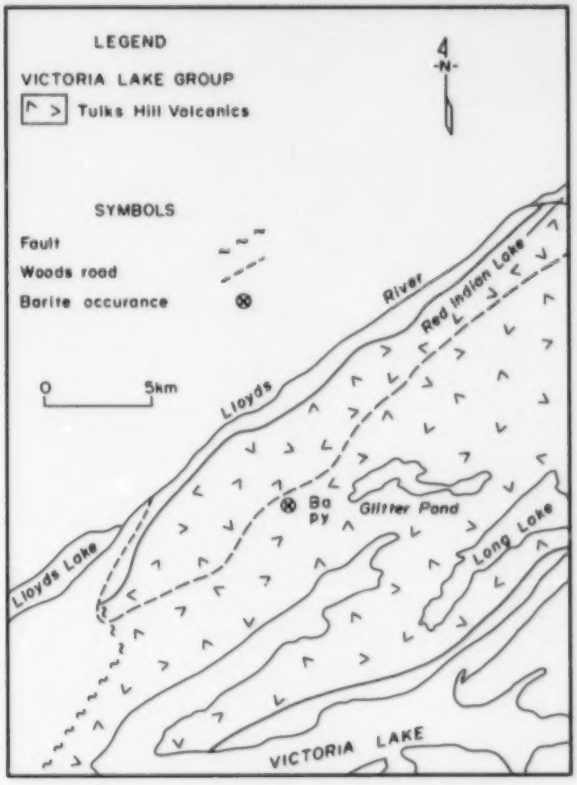


Figure 15. *Location of the Glitter Pond barite vein.*

The deposit occurs in the Upper Ordovician Tulks Hill volcanic rocks of the Victoria Lake Group. The immediate host rock is mottled, brownish green, sericitic, chloritic tuff with a strong fabric that trends 250° and dips vertically. A narrow, vertically dipping mafic dyke cuts the deposit. Abitibi-Price-Asarco (date unknown) tested the deposit with three short diamond drill holes, all of which were drilled from the same collar; no assays are available from this work. The author examined and took grab samples from the showing in 1984 the results of which are shown in Table 15. The deposit is too small and impure to be of commercial interest.

Table 15. Assays from the Glitter Pond barite prospect

Sample No.	Description	$BaSO_4$	$SrSO_4$	Ca	Cu	Pb	Zn
AH-84-09	grab; barite–quartz (white)	32.02	0.30	0.01	<0.01	<0.01	<0.01
AH-84-10	grab; barite–quartz (rusty)	54.18	0.34	0.02	<0.01	<0.01	<0.01
AH-84-11	grab; barite–quartz	46.72	1.33	0.14	<0.01	<0.01	<0.01

Sampled by A.F. Howse (1984)

BAY D'ESPOIR AREA BARITE OCCURRENCES

GEOLOGICAL SETTING

Most of the documented occurrences of barite in the Bay d'Espoir area consist of quartz ± barite veins that host a variety of metals. The veins occur in metasedimentary rocks of the Baie d'Espoir Group and comprise the central part of a well defined pattern of mineralization along the southeastern margin of the North Bay Granite, to which they appear to be genetically linked (Colman-Sadd and Swinden, 1982). Molybdenite showings exist nearer the granite.

The best concentration of quartz–barite veins is located on or near the shore of Lampidoes Passage in Bay d'Espoir (Figure 16). Similar veins are found on the barrens above the passage. These veins were prospected for base- and precious metals by NALCO prospectors in the early 1950's (Dunlop, 1954; McPhar Geophysics 1955) and were re-examined and sampled in 1980 (Colman-Sadd and Swinden, 1982). The latter study confirmed the presence of local concentrations of disseminated pyrite, chalcopyrite, sphalerite and galena but selected sampling returned much lower values than the relatively good lead and silver reported by Dunlop (1954).

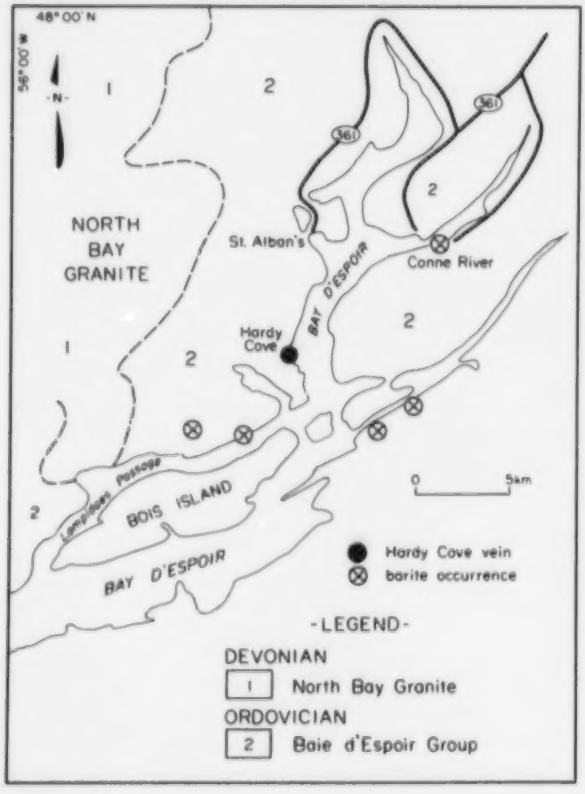


Figure 16. *Location of barite occurrences in the Bay d'Espoir area (geology after Colman-Sadd, 1976).*

The above veins were re-examined by the author in 1983 in light of their barite potential. In nearly all cases it was found that the veins were too small and barite content to little to be of economic interest. One possible exception is the vein located in Hardy Cove, in which barite is the main constituent mineral. The following is a descriptive account of the vein:

Hardy Cove Vein

The Hardy Cove vein was discovered by NALCO prospectors in the early 1950's, and is located on the shore of Hardy Cove, a tiny indentation on the east side of Roti Point. A 1954, assessment of the prospect by NALCO included some trenching and 6 diamond drill holes with average depths of 75 m. This work did not identify significant amounts of base metals although some trench samples assayed high lead and silver.

The deposit consists of anastomosing veins of white granular barite and associated quartz, which contain patches of coarse grained galena, having dimensions up to 10 cm². There are two main veins exposed both of which appear to be part of the same structure. The largest vein, which pinches and swells up to 70 cm, strikes 350° and dips vertically (Plate 18). A smaller vein branches eastward from the main structure, is concordant with the schistosity of the host metasediments, and appears to contain more galena. The total exposed length of the larger vein is approximately 7 m, measured from its northern end (under salt water) to the point where it becomes obscured by overburden at its south end. This latter section is offset 1 m to the west by a fault.

Plate 18. *Barite–quartz vein at Hardy Cove, Bay d'Espoir.*

In 1983, the author cut two channel samples across a section of the Hardy Cove vein. The samples averaged 79.3

percent $BaSO_4$ and 19.2 percent SiO_2. The smaller offshoot vein assayed substantially lower barite and higher silica. Significant silver values were recorded with one sample of a galena-rich siliceous zone giving 51.1 ppm (g/t) (Table 16).

Table 16. Assays from the Roti Point area, Bay D'Espoir

Sample No.	Location	Remarks	$BaSO_4$	$SrSO_4$	Cu	Pb	Zn	CaO	SiO_2	PPM Ag
5140035	Roti Point	quartz–barite with galena	0.61	0.02	0.01	1.36	0.01	0.24	89.05	11.5
5140036	Roti Point	quartz–barite with galena	10.07	0.10	0.04	5.64	1.36	0.40	74.80	37.6
5140038	Hardy Cove	small offshoot vein	47.3	1.36	0.01	7.35	0.01	0.05	38.20	25.4
5140039	Hardy Cove	grab; galena-rich zone	7.09	0.10	0.40	5.16	0.01	0.07	79.40	51.1
5140049	Hardy Cove	grab; galena-rich zone	1.78	0.01	0.09	1.99	9.71	0.13	81.00	15.4
5140052	Hardy Cove	channel; 0–15 cm	71.8	2.12	0.01	0.97	0.01	0.10	24.70	4.8
5140053	Hardy Cove	channel; 15–30 cm	86.91	2.41	0.01	0.04	0.01	0.01	13.60	0.1

Sampled by A.F. Howse and C.J. Collins (1983)

CONCLUSIONS

Barite deposits of potential economic interest are found in three different geological settings in insular Newfoundland. The largest potential source of barite is contained in the Buchans tailings, which accumulated from the mining of barite polymetallic sulphide bodies hosted by the Middle Ordovician Buchans Group of mafic to felsic volcanic rocks. This reserve and recovery plant have the capability of supplying Newfoundland's offshore requirements for drilling-mud barite. To date, production and transportation costs and problems related to markets and competition have prevented this operation from realizing its potential.

Precambrian rocks of the Avalon Platform host numerous, small, high-purity barite veins. However, despite the ubiquity of these occurrences, no significant reserves have been identified. The largest of these veins, the Collier Point deposit, was sporadically mined between 1982 and 1985 with the barite used as a weighting agent in offshore drilling muds. There has been no systematic attempt to measure the amount of barite remaining at Collier Point but field observations indicate a few thousand tonnes of recoverable material remain. There are obvious advantages to mining Avalon barite veins should sufficient reserves be identified. They are close to tidewater and the grade is such that simple grinding is all the processing required to make the ore suitable for use in drilling fluids. Other potential industrial applications include the production of pharmaceutical barite, and barium chemicals.

Deposits of mixed barite and celestite are found at the contact between the Carboniferous Codroy Group and the Ordovician Table Head Group on the Port auPort Peninsula. This area has good potential for yielding additional deposits of potential economic interest.

ACKNOWLEDGMENTS

Thanks are expressed to all those who helped in the preparation of this report. A special acknowledgement is made of the field work ably performed by C.J. Collins, V.A. French, K. Freake, P. Bull, L. White and P. Spurrell. The manuscript benefited from critical reviews by H.S. Swinden and C.F. O'Driscoll. P.L. Dean is thanked for advice during the project and also for reviewing an earlier draft of the report. Geochemical analyses were carried out by the staff of the Geochemical Laboratory, Newfoundland Department of Mines and Energy, in their usual efficient manner under the direction of P.H. Davenport. Drafting expertise was provided by the Cartographic Unit, Department of Mines and Energy, under the supervision of Ken Byrne.

REFERENCES

Ampian, S.G.

1985: Barite. *In* Mineral Facts and Problems. Bulletin 675, U.S. Department of the Interior, Washington, D.C., 10 pages.

1989: Barite. *In* Minerals Yearbook–1989. U.S. Department of the Interior–Bureau of Mines, Washington, D.C., 12 pages.

Anderson, M.M.
1981: The Random Formation of southeastern Newfoundland: a discussion aimed at establishing age and relationship to bounding formations. American Journal of Science, Volume 281, pages 807-830.

Anonymous
1981: The Buchans Barite Plant; educational pamphlet. ASRCO and Abitibi-Price, Buchans, Newfoundland, 4 pages.

Baird, D.M. and Côté, P.R.
1964: Lower Carboniferous sedimentary rocks in southwestern Newfoundland and their relations to similar strata in western Cape Breton Island. Bulletin of the Canadian Institute of Mining and Metallurgy, Volume 57, pages 509-520.

Baird, D.M. and Snelgrove, A.K.
1953: Mines and Mineral Resources of Newfoundland. Geological Survey of Newfoundland Info. Circular No. 4, 149 pages.

Bell, K., Blenkinsop, J. and Strong, D.F.
1977: The geochronology of some granitic bodies from eastern Newfoundland and its bearing on Appalachian evolution. Canadian Journal of Earth Sciences, Volume 14, Number 3, pages 456-476.

Bell, W.A.
1948: Early Carboniferous strata of the St. George's Bay area, Newfoundland. Geological Survey of Canada, Bulletin 10, 45 pages.

Blackwood, R.F.
1978: Northeast Gander Zone in Newfoundland. *In* Report of Activities for 1977. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 78-1, pages 72-79.

Blount, C.W.
1977: Barite solubilities and thermodynamic quantities up to 300°C and 1400 bars. American Mineralogist, Volume 62, No. 9-10, pages 942-957.

Bradley, D.A.
1955: Report on the Sulphide Veins, Rencontre East Area; Fortune Bay; Private Report. Newfoundland and Labrador Corporation, 5 pages.

Brobst, D.A.
1980: Barite resources in their geologic framework. *In* Proceedings of Minerals and Chemicals in Drilling Muds. *Edited by* P.W. Harben. Industrial Minerals, pages 30-39.

Brown, P.A. and Colman-Sadd, S.P.
1976: Hermitage Flexure: figment or fact? Geology, Volume 4, pages 561-564.

Carr, G.F.
1958: The Industrial Minerals of Newfoundland. Canada Department of Mines and Technical Surceys, Mines Branch No. 855, 156 pages.

Chute, N.E.
1939: Mineral Deposits of the Placentia Bay Area. Unpublished Report. Geological Survey of Newfoundland. Nfld. MDD File–1N(11).

Collins, C.J.
1984: Genesis of the St. Lawrence fluorite veins, as indicated by fluid inclusion and trace element data from three selected veins. Unpublished B.Sc thesis, Memorial University of Newfoundland, St. John's, 103 pages.

Collins, R.K. and Andrews, P.R.A.
1988: Summary Report No. 1: Barite; CANMET Report 88–2E. CANMET, Energy Mines and Resources Canada, 64 pages.

Colman-Sadd, S.P.
1976: Geology of the St. Alban's map area, Newfoundland (1M/13). Newfoundland Department of Mines and Energy, Mineral Development Division, Report 76-1, 19 pages.

Colman-Sadd, S.P. and Swinden, H.S.
1982: Geology and economic potential of south-central Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 82-8, 102 pages.

Crowley, R.
1978: Report on Exploration for 1977 on the Brinex White Bay Concession, Sops Arm area and Gales Brook claim group. Noranda Exploration Ltd. Unpublished report, 12H(527).

D.S. Robertson Associates Limited
1972: St. Lawrence Area: 20 D.D.H. Logs, 1 Geology Map. Unpublished Report. Nfld. MDD File–1L/14(43).

Dean, P.L.
1977: Report on the Geology and Metallogeny of the Notre Dame Bay area, to accompany maps 12H/1,8,9, and 2E/3,4,5,6,7,8,9,10,11,12. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 77-10.

Dimmell, P.M.
1978: Report on Claim numbers 11097–11124, Gales Brook area for Noranda Exploration Co. Ltd. unpublished report, 12H(533).

Dix, C.R.
1981: The Codroy Group (Upper Mississippian) on the Port au Port Peninsula, Western Newfoundland: stratigraphy, palaeontology, sedimentology and diagenesis. Abstract, M.Sc. thesis, Memorial University of Newfoundland, St. John's.

Dunlop, W.B.
1953: Preliminary Report of the Bay d'Espoir Area. Private Report, Newfoundland and Labrador Corporation.

Dunlop, W.B.
1953: Notes on showings of Bay d'Espoir. NALCO unpublished report, 3 pages. 1M(30).

Dunning, G.R., Kean, B.F., Thurlow, J.G. and Swinden, H.S.
1987: Geochronology of the Buchans, Roberts Arm, and Victoria Lake groups and Mansfield Cove Complex, Newfoundland. Canadian Journal of Earth Sciences, Volume 24, pages 1175-1184.

Felderhof, G.W.
1978: Barite, celestite and fluorite in Nova Scotia. Bulletin 4, Department of Mines and Energy, Halifax, N.S., 463 pages.

Fletcher, T.P.
1972: Geology and Lower Middle Cambrian trilobite faunas of the southwest Avalon, Newfoundland. Ph.D. thesis, University of Cambridge, 236 pages.

Fogwill, W.D.
1970: Mineral Deposits and Prospecting Environments of Newfoundland. Newfoundland Department of Mines, Agriculture and Resources, Information Circular No. 14, 45 pages.

Greene, B.A.
1962: Cambrian Rocks of Western St. Mary's Bay Area, Avalon Peninsula, Newfoundland. M.Sc. Thesis, Memorial University of Newfoundland.

Grice, M.A.K.
1974: Mineral processing investigation, Ronan barite/celestite deposit, Boswarlos, Port au Port Peninsula, Newfoundland. Atlantic Industrial Research Institute, Halifax, Nova Scotia, 11 pages.

Griffiths, J.
1984: Barytes: non-drilling applications. In Industrial Minerals. No. 201, June, 1984, pages 21-33.

Griffiths, Joyce
1992: "Barytes Fillers in Recession–More of a Weighting Game". Industrial Minerals, no. 293, Feb. pages 39-49.

Guillet, G.R. and Kriens, J.
1984: Ontario and the Mineral Filler Industry. Ontario Ministry of Natural Resources, Mineral Resources Branch, Industrial Mineral Background Paper 5 (IMP5), 175 pages.

Haines, S.K.
1979: Barite. *In* Mineral Commodity Profiles. Bureau of Mines, U.S. Department of the Interior, Washington, D.C., 13 pages.

Hanor, J.S.
1979: The sedimentary genesis of hydrothermal fluids. *In* Geochemistry of Hydrothermal Ore Deposits, 2nd. edition. *Edited by* H.L. Barnes. Toronto. Wiley-Interscience, Ch. 4.

Hanor, J.S. and Baria, L.R.
1977: Controls on Distribution of Barite in Arkansas. *In* Symposium on the Geology of the Ouachita Mountains. *Edited by* C.G. Stine. Volume 2, pages 42-49.

Harben, P.W. and Bates, R.L.
1984: Geology of the nonmetallics. Metal Bulletin Inc., New York, 392 pages.

Hartman F.H. and Wyman, R.A.
1974: Recovery of Barite from Buchans Tailings, Buchans Newfoundland. Division Report 74-17, CANMET, Energy Mines and Resources Canada, 1 page.

Higgins, N.C.
1980: The genesis of the Grey River tungsten prospect: a fluid inclusion, geochemical and isotopic study. Ph.D. thesis, Memorial University of Newfoundland, St. John's, 540 pages.

Hodych, J.P.
1974: Report on gravity survey from the Ronan barite/celestite deposit, Boswarlos, Port au Port Peninsula. Prepared for Newfoundland Department of Mines and Energy, Mineral Development Division, 12B/10 (243).

Howley, J.P. and Murray, J.P.
1918: Reports of the Geological Survey of Newfoundland from 1881-1909. St. John's, 1918.

Howse, A.F., Butler, A.J. and Collins, C.J.
1984a: Stream sediment geochemistry of the Bellevue map area (1N/12) Avalon Peninsula, Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Newfoundland MDD File–Nfld (452), 20 pages.

1984b: Stream sediment geochemistry of the St. Brides area (1L316), Avalon Peninsula, Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Newfoundland MDD File–Nfld 1L/16(91), 18 pages.

1986: Stream sediment geochemistry of the St. Lawrence area, Burin Peninsula, Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Newfoundland MDD File–Nfld (1499), 16 pages.

Howse A.F. and Collins, C.J.
1984: Barite evaluation in three areas of southeastern Newfoundland. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 84-1, pages 263-266.

Howse, A., Dean, P., Swinden, S., Kean, B. and Morrisey, F.
1983: Fluorspar deposits of the St. Lawrence area, Newfoundland: Geology and economic potential. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 83-9, 21 pages.

Howse, A.F. and French, V.A.
1983: Barite evaluation eastern and western Newfoundland. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 83-1, pages 150-156.

Howse, A.F. and Maloney, J.
1984: Barite deposits of the Avalon Peninsula. *In* Mineral Deposits of Newfoundland–a 1984 Perspective. *Compiled by* H. Scott Swinden. Newfoundland Department of Mines and Energy, Mineral Development Division, pages 173-177.

Hughes, C.J. and Malpas, J.G.
1971: Metasomatism in the Late Precambrian Bull Arm Formation in southeastern Newfoundland; recognition and implications. Geological Association of Canada, Proceedings, Volume 24, No. 1, pages 85-93.

Jewell, W.B.
1939: Geology and mineral deposits of the Bay d'Espoir area. Geological Survey of Newfoundland, Bulletin No. 17.

Johnson, H.
1954: The strontium deposits of Port au Port Peninsula. Geological Survey of Canada, Bulletin 27 (Contributions to the economic geology of western Newfoundland), 1954, pages 1-19.

Jones, G.K.
1978: Industrial minerals in oil production. *In* Raw Materials for Oilwell Drilling. *Edited by* P.W. Harben. Metal Bulletin Inc., pages 11-30.

Kauffmann, R.
1936: Reconnaissance of the regional and economic geology of the St. Lawrence area, with notes on fluorite. B.A. thesis, Princeton University, Princeton, New Jersey. (1L/14 20).

King, A.F.
1985: Geology of the St. John's (1N/10a,b), Cochrane Pond (1N/7f, north half), Torbay (1N/10g, south half), Petty Harbour (1N/7g, north half), Windsor Lake (1N/10c), Bauline Line (1N/10N, south half), and Topsail (1N/10d, east half) areas. Newfoundland Department of Mines and Energy, Mineral Development Division, Maps 8567-8573.

1988: Geology of the Avalon Peninsula (parts of 1K,1L,1M,1N and 2C). Newfoundland Department of Mines, Mineral Development Division, Map 88-1.

Knight, I.
1983: Geology of the Carboniferous Bay St. George Subbasin, western Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Memoir 1, 358 pages.

Knight, I. and Boyce, W.D.
1984: Geological mapping of the Port Saunders (12I/11), St. John Island (12I/14) and parts of the Torrent River (12I/10) and Bellburns (12I/6) map sheets, northwestern Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 84-1, pages 114-124.

Krogh, T.E.
1982: Improved accuracy of U–Pb zircon ages by the creation of a more concordant systems using an air abrasion technique. Geochimica et Cosmochimica Acta, Volume 46, pages 637-649.

Lundie, P.
1978: Barytes–its use in drilling mud. *In* Raw Materials for Oilwell Drilling. *Edited by* P.W. Harben. Metal Bulletin Inc., pages 31-36.

Maloney, J.A.
1991: The origin of barite and related veins on the Avalon Peninsula of Newfoundland. Unpublished M.Sc. thesis, Memorial University of Newfoundland, 258 pages.

McArthur, J.G.
1972: Unpublished notes on a barite survey. Newfoundland Department of Mines and Energy, Mineral Development Division, 4 pages.

1973: Barite and Celestite Deposits in Newfoundland. Presented at the Annual Convention of Prospectors and Developers Association, 1973. Open File NFLD 601, 21 pages.

McArthur, J.G., Davenport, P.H. and Howse, A.F.
1975: A geochemical reconnaissance survey of the Carboniferous Codroy–Bay St. George Basin, Newfoundland; Part II, Barium, strontium and manganese in stream sediments. Newfoundland Department of Mines and Energy, Mineral Development Division, Open File Nlfd. 876.

McCartney, W.D.
1954: Holyrood, Newfoundland. Geological Survey of Canada, Preliminary Map 54-3.

1956: Dildo, Newfoundland. Geological Survey of Canada, Map 13-1956.

1956a: Argentia, Newfoundland. Geological Survey of Canada, Paper 55-11.

1956b: Dildo, Newfoundland. Geological Survey of Canada, Map 13-1956.

1958: Sunnyside, Newfoundland. Geological Survey of Canada, Paper 58-8.

1967: Whitbourne map area, Newfoundland. Geological Survey of Canada, Memoir 341.

McHale, K.B. and McHale, D.E.
1984: (Abstract) Oil Limited, and Ordovician volcanogenic sulfide Prospect. Geological Association of Canada, Newfoundland Section, Annual Spring Meeting, Program with Abstract, page 5.

McPhar Geophysics Ltd.
1955: Report on the electromagnetic survey of the Roti Point Group, Bay d'Espoir area, Newfoundland. For Newfoundland and Labrador Corporation. Unpublished report, 6 pages. 11P/9 (3).

Milne, J.
1874: Notes on the physical features and mineralogy of Newfoundland. Quarterly Journal, Geological Survey of London, Volume 30, pages 722-745.

Murray, A. and Howley, J.P.
1918: Reports of the Geological Survey from 1881-1909. Geological Survey of Newfoundland.

Newfoundland Fluorspar Limited
1976: St. Lawrence area, Newfoundland, DDH records by Newfluor. Newfoundland Department of Mines and Energy, File 1L/14 (55).

Nowlan, G.S. and Thurlow, J.G.
1984: Middle Ordovician conodonts from the Buchans Group, central Newfoundland, and their significance for regional stratigraphy of the Central Volcanic Belt. Canadian Journal of Earth Sciences, Volume 21, pages 284-296.

O'Brien, S.J., Strong, P.G. and Evans, J.L.
1977: The Geology of the Grand Band (1M/4) and Lamaline (1L/13) map areas, Burin Peninsula, Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 77-7, 16 pages.

O'Driscoll, C.F. and King, A.F.
1985: Mineral occurrences map of the Avalon Peninsula. Newfoundland Department of Mines and Energy, Mineral Development Division, Map 85-62.

Puchelt, H.
1967: Zur Geochemie des Barium im exogen Zyklus. Sitzungsber. Heidelberger Akad. Wissenschaften, Math. naturwissenschaft. Klasse.

Riley, G.C.
1962: Stephenville map-area, Newfoundland. Geological Survey of Canada, Memoir 323, 72 pages.

Ronan, J.J.
1942: Boswarlos Barite/Celestite Deposit. Unpublished Report, Geological Survey of Newfoundland, 5 pages. 12B/10 (25).

Smith, B.L. and White D.E.
1956: Geology of the Recontre East area. Geological Survey of Canada, Open file 50.

Smith, W.S.
1957: St. Lawrence area, Newfoundland–report on Fluorspar. Unpublished report for Newfoundland Fluorspar Limited, Nfld. MDD File–1L/14(16), 113 pages.

Smyth, W.R. and Schillereff, H.S.
1982: The pre-Carboniferous geology of southwest White Bay. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 82-1, pages 78-98.

Stone, W.J.D., Nye, J.D. and Farr, I.R.
1980: X-ray barium sulphate for North America. CIM Bulletin, August 1980, pages 85-88.

Strong, D.F., O'Brien, S.J., Strong, P.G., Taylor, S.W. and Wilton, D.H.
1978: Geology of the Marystown (1M/3) and St. Lawrence (1L/14) map areas, Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 77-8, 81 pages.

Strubel, G.
1966: Die Hydrothermale Lostichkeit Von Colestin in System $SrSO_4$–NaCL–H_2O. Neues Jahrb. Mineral. Montash., pages 99-108.

Swanson, E.A., Strong, D.F. and Thurlow, J.G.
1981: The Buchans Orebodies: Fifty Years of Geology and Mining. Geological Association of Canada, Special Paper 22, 350 pages.

Templeton, C.C.
1960: Solubility of barium sulphate in sodium chloride solutions from 250 to 950. Journal of Chemical Engineering Data, pages 514-516.

Teng, H.C.
1974: A Lithogeochemical Study of the St. Lawrence Granite, Newfoundland. Unpublished M.Sc. thesis, Memorial University of Newfoundland, St. John's, 194 pages.

Teng, H.C. and Strong, D.F.
1976: Geology and Geochemistry of the St. Lawrence peralkaline granite and associated fluorite deposits, southeastern Newfoundland. Canadian Journal of Earth Sciences, Volume 13, pages 1374-1385.

Thurlow, J.G. and Swanson, E.A.
1981: Geology and ore deposits of the Buchans area, central Newfoundland. Geological Association of Canada, Special Paper 22, pages 114-142.

Tod, Joan
1986: VLF-EM Investigations in insular Newfoundland. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 86-1, pages 239-250.

Uchameyshvili, N. Ye., Malinin, S.D. and Khitarov, N.I.
1966: Solubility of barite in concentrated chloride solutions of some metals at elevated temperatures in relation to problems of the genesis of barite deposits. Geokhimiya, pages 1193-1205.

Van Alstine, R.E.
1948: Geology and mineral deposits of the St. Lawrence area, Burin Peninsula, Newfoundland. Geological Survey of Newfoundland, Bulletin 23, 64 pages.

Wagenbauer, H.A., Riley, C.A. and Dave, G.
1983: Geochemical laboratory–description of analytical procedures. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 83-1, pages 133-137.

Walthier, T.N.
1949: Geology and Mineral Deposits of the area between Corner Brook and Stephenville, Western Newfoundland, Part I; Geology and Mineral Deposits of the area between Lewis Hills and Bay St. George, Newfoundland, Part II; Geological Survey of Newfoundland, Bull. 35, 87 pages.

Williams, H.
1964: The Appalachians in Northeastern Newfoundland–a two-sided symmetrical system. American Journal of Science, Volume 262, pages 1137-1158.

1979: Appalachian Orogen in Canada; Canadian Journal of Earth Science, Tuzo Wilson Volume, v. 16, pages 792-807.

Williams, H., Kennedy, M.J. and Neale, E.R.W.
1970: The Hermitage Flexure, the Cabot Fault, and the disappearance of the Newfoundland Central Mobile Belt. Geological Society of America Bulletin, Volume 81, pages 1563-1568.

1972: The Appalachian structural province. *In* Tectonic Styles in Canada. *Edited by* R.A. Price and R.J.W. Douglas. Geological Association of Canada, Special Paper 11, pages 181-261.

1974: The northeastward termination of the Appalachian orogen. *In* The Oceans Basins and Margins, Volume 2–North Atlantic. *Edited by* A.E.M. Nairn and F.G. Stehli. New York, Plenum, pages 70-123.

Williamson, D.H.
1956: Geology of Oderin Island and adjacent Islands, Placentia Bay. Geological Survey of Newfoundland, Report No. 9, 34 pages.